Physicochemical Properties and Cooking Quality of Microwave-Dried Rice

J. I. WADSWORTH and S. P. KOLTUN[1]

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ABSTRACT

Starbonnet and Labelle varieties of long-grain rice and Nato variety of medium-grain rice were dried under vacuum with microwave energy to determine the effects of microwave-vacuum (MV) treatments on the physicochemical properties and eating characteristics of the milled rice. Milled rice was evaluated by alkali reaction, water-uptake capacity, amylographic gelatinization and pasting characteristics, and taste panel. There were no significant differences between the air-dried controls and the MV treatments for both peak viscosity and setback viscosity. The alkali-spreading values and water-uptake capacities for some of the MV-treated samples were statistically slightly greater than the control samples; however, the differences were not great enough to be of any practical consequence. The taste panel could not distinguish between MV-treated samples and the controls. MV techniques can be used to dry rice without materially altering the cooking and eating characteristics.

The energy crises of the seventies demonstrated a need for multiple sources of energy; and, with the current world political situation, there still exists the possibility that supplies of natural gas and oil could become restricted and more expensive. In the event that such a circumstance were prolonged, grain processors would be forced to seek alternative energy sources for drying. It seems likely that electrical power, generated from coal or nuclear energy, will be a prime alternative. Microwave-vacuum (MV) is one technique for using electric power in grain drying. Wear (1979), Gardner and Butler (1980), and Wadsworth (1984) reported on drying rice under vacuum using microwaves. While MV drying has been demonstrated to be an alternative means for drying rice, the process will not be acceptable to the rice industry unless rice dried by this method has the cooking and processing characteristics of conventionally dried rice.

Hogan and Planck (1958) reported that drying conditions can influence the hydration characteristics of rice. Goebel et al (1984) reported the effects of microwave energy on wheat starch granule transformations. It is known that microwaves can have subthermal effects (Copson 1975), and anyone who has heated bakery products in a microwave oven is aware of the textural changes that can result. The purpose of this investigation was to determine the effect of MV-drying treatments on the physicochemical properties that are indexes of cooking and eating quality of milled rice.

MATERIALS AND METHODS

Rice

Six green rice lots used in this study (Table I) were from two long-grain varieties (Labelle and Starbonnet) and one medium-grain variety (Nato) grown over three seasons. The rice lots, grown in the vicinity of Crowley, LA, were obtained from a commercial seed rice processor. The rough rice was cleaned with a Carter dockage tester. The cleaned green rough rice was stored at 3°C during the course of the drying experiments. Previous experience has shown that the quality of green rice does not change when stored at this temperature for up to six months.

Drying

The rice samples were dried in a batch-operated laboratory-scale microwave dryer manufactured by the Aeroglide Corp. (Fig. 1). A 4,536-g rice sample was spread in a thin layer (approximately 2 cm thick) on a turntable. The rotating turntable was suspended in the vacuum chamber from a strain gauge to enable continuous measurement of sample weight during drying. An infrared temperature sensor measured temperature changes. Control samples were shade dried at ambient temperature and humidity (22°C, 60% rh).

The initial moisture contents of the rice lots ranged from 17.8 to 22.0% (wb). The samples were dried in a single pass to a final moisture content of approximately 13%. The dryer was operated at three microwave power levels (600, 1,200, and 2,000 watts) and three vacuum levels for each power level (Table II). Drying rates

TABLE I
Variety, Crop Year, and Initial Moisture Content (wet basis) of the Rice Lots[a]

Variety	Grain Type	Crop Year	Moisture Content (%)
Starbonnet	Long	1981	22.0
Labelle	Long	1982	19.4
Labelle	Long	1983	19.5
Nato	Medium	1981	17.5
Nato	Medium	1982	20.1
Nato	Medium	1983	18.3

[a] All rice lots were grown in the vicinity of Crowley, LA.

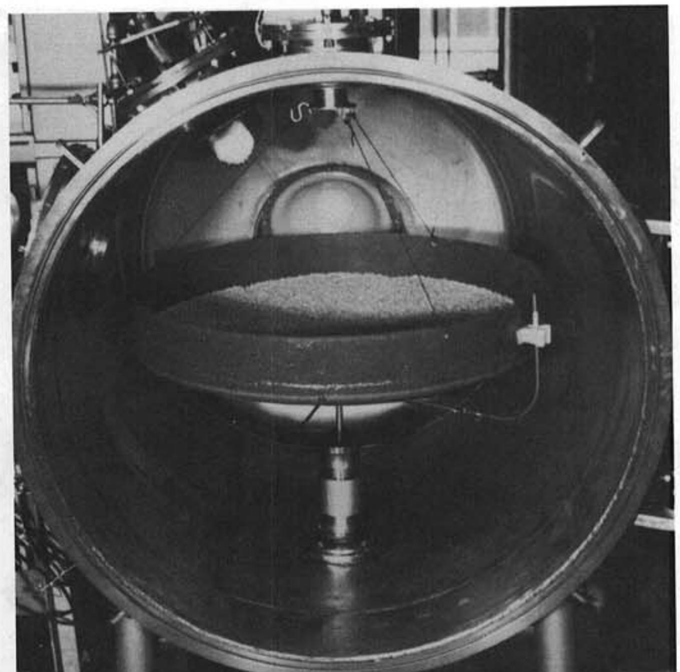

Fig. 1. Interior view of the laboratory-scale microwave-vacuum dryer showing the rice sample spread in a thin layer on a turntable suspended from a strain gauge.

[1] Chemical engineer and research leader, respectively, U. S. Department of Agriculture, Agricultural Research Service, Southern Regional Research Center, New Orleans, LA 70179.

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ranged from 50 g of water removed per hour per kilogram of rice (approximately the same as conventional drying) to 260 $g \cdot hr^{-1} \cdot kg^{-1}$. Drying times were adjusted to achieve the desired final moisture content. Two replicate runs were made for each set of drying conditions.

Milling

The MV-dried samples were allowed to equilibrate with the milling room environment (22°C, 60% rh) for two weeks before milling. Milling moisture content was approximately 12.1 ± 0.3%. One thousand grams of rough rice was shelled in the McGill sheller and then milled in the McGill mill in accordance with directions in the USDA Rice Inspection Handbook (USDA 1974). Well milled rice was obtained for all samples.

Physicochemical Properties

The tests used in this study were selected from those used to evaluate the cooking quality of milled rice at the USDA Rice Quality Laboratory (Webb 1980); these were: water-uptake capacity at 77°C, alkali spreading reaction, and amylographic gelatinization and pasting characteristics. All rice samples were equilibrated to 12% moisture and only head rice (whole grain rice) was used in the evaluations. Water-uptake and alkali-spreading values were determined with the methods described by Halick and Kelly (1959) and Little et al (1958), respectively. To improve the precision of the alkali-spreading values, 60 kernels were used for each determination. Peak and setback viscosities were obtained with a Brabender type VA-VE viscoamylograph using a 1,000 cm-g cartridge. The procedures of Halick and Kelly (1959) were followed.

Taste Test

An informal taste panel evaluated the flavor and texture of cooked rice samples. The eight panel members, all of whom eat rice on a regular basis, had previous taste panel experience. The samples were cooked with one part rice to 1.5 parts water in a food steamer for 20 min. At each panel session one MV-dried sample was compared with the control sample using a triangle test. The order of presentation of the samples to the panel was randomized. The panelists were asked to identify the sample that was different by either flavor or texture.

RESULTS AND DISCUSSION

The MV conditions (Table II) were selected so that they spanned a range of mild to harsh treatments. The drying rates obtained ranged from two to 24 percentage points decrease in moisture content per hour. The head rice yields (percent unbroken kernels) for the milder treatments were comparable to those for the controls, whereas the harsh treatments gave head yields as low as 13%. Only head rice was used in the quality evaluations.

The results of the alkali reaction tests are shown in Table III. Analysis of variance (ANOVA) indicated significant differences among the rice lots ($P < 0.001$) and among treatments ($P < 0.05$). For each variety, the control was compared with each treatment using Fisher's least significant difference (LSD) test. This indicated that the alkali-spreading values for some of the samples receiving the more severe MV treatments were significantly higher ($P < 0.05$) than the controls. However, based on experience, we believe that these differences (less than 1.0 units) are not great enough to be of any practical consequence in terms of rice quality.

Similar results were obtained with the water-uptake capacity tests (Table IV). ANOVA indicated significant differences among rice lots ($P < 0.001$) and among treatments ($P < 0.05$). Some of the more severely treated samples had significantly higher water uptake when compared with their controls (Fisher's LSD, $P < 0.05$). However, the differences were too small to substantially affect rice cooking and processing quality.

A possible explanation for the higher alkali-spreading values and higher water-uptake capacities associated with the more severe MV treatments might be that the more severely treated samples had small fractures in the head rice kernels. Matthews et al (1970) reported a high positive correlation between breakage and fractures in conventionally dried rice kernels. The more severely treated microwave-dried samples had more broken kernels; thus, it seems likely that the head rice in these samples would have more fractures. These cracks would allow alkali solution or hot water to infuse the kernels at a slightly greater rate than for uncracked kernels, resulting in the slightly higher test values.

Table V gives the peak viscosities and setback viscosities as measured with a Brabender viscoamylograph. The amylographic viscosity curves for the control and the MV-treated samples were essentially identical within each rice lot. ANOVA indicated significant differences among rice lots ($P < 0.001$) but not among treatments for both peak and setback viscosities. By applying Fisher's LSD test, two cases were identified where a treated sample was different from the control. These two were not the more severely treated samples and, considering the number of statistical tests made, the indicated significance was probably due to random chance. It seems safe to conclude that the MV treatments did not

TABLE II
Microwave-Vacuum Drying Conditions[a]

Drying Code	Microwave Power (kW/kg)	Dryer Pressure (torr)	Drying Time (min) Starbonnet 1981	Labelle 1982	Labelle 1983	Nato 1981	Nato 1982	Nato 1983
MV11	0.132	20	54	49	50	42	48	44
MV12	0.132	100		65	68	58	67	61
MV13	0.132	400		98	99	88	100	92
MV21	0.264	50	34	33	33	28	30	29
MV22	0.264	100		37	37	32	37	34
MV23	0.264	400		47	48	40	46	42
MV31	0.441	60	18	18	18	14	16	15
MV32	0.441	100		21	21	18	21	19
MV33	0.441	400	30	28	28	25	29	26

[a] Control samples were shade dried at 22°C and 60% relative humidity.

TABLE III
Alkali-Spreading Values for Microwave-Vacuum-Dried Rice

Drying Code	Starbonnet 1981	Labelle 1982	Labelle 1983	Nato 1981	Nato 1982	Nato 1983
MV11	4.6	2.5	3.2	6.6	6.2	6.6
MV12		2.9	3.2	6.2	6.2	6.2
MV13		3.2*[a]	3.3	6.2	6.4	6.2
MV21	4.3	2.8	3.1	6.4	6.1	6.3
MV22		2.5	3.5	6.5	6.3	6.5
MV23		3.3*	3.4	6.5	6.4	6.6
MV31	4.5	2.4	3.4	6.4	6.3	6.4
MV32		2.5	3.3	6.6	6.7*	6.8
MV33	4.9*	3.4*	3.8*	6.8	6.7*	6.7
Control	4.3	2.5	3.0	6.3	6.1	6.2

[a] *, Significantly different from the control at $P < 0.05$ (LSD = 0.6).

TABLE IV
Water Uptake Values for Microwave-Vacuum-Dried Rice

Drying Code	Water Uptake (ml/100 g)[a] Starbonnet 1981	Labelle 1982	Labelle 1983	Nato 1981	Nato 1982	Nato 1983
MV11	114	62	132	214	234	310
MV12		84	130	210	219	332
MV13		74	125	263*	229	297
MV21	106	73	128	177	255	335
MV22		84	126	225	262	338
MV23		66	133	227	246	351*
MV31	138	114*[b]	124	237	253	340
MV32		75	136	215	248	350*
MV33	115	105*	144	235	268*	354*
Control	123	72	124	225	236	316

[a] Water uptake measured at 77°C.
[b] *, Significantly higher than the control at $P < 0.05$ (LSD = 28).

materially affect the cooking and processing quality of the milled rice.

The results of the taste panel evaluation for the Labelle 1982 and Nato 1982 MV-dried samples are shown in Tables VI and VII. At a panel session, each member was presented three samples of which two were identical. The panelist was asked to identify the one that was different by either taste or texture. Thus, the probability of a correct identification being made by random chance was one-third. The hypothesis was that there is no difference between the control and the MV-treated sample. The information in Table VI shows the number of times a given sample was correctly or incorrectly identified by a panelist as different from the control. The chi-square test (Li 1957), which is a measure of how far the results deviated from the expected probability of one-third correct judgments, indicated that the panel as a whole could not distinguish between the flavor or texture of the control and those of the MV-treated sample.

Table VII shows the performance of the individual panelists in correctly distinguishing between MV-dried samples and the control. The "random chance probability" is the probability that a panelist would, by random chance alone, get a number of correct responses equal to or greater than the number actually attained. The best performance by any of the eight panelists was eight correct out of 18 sessions. The probability of getting eight or more correct out of 18 tries by random chance is 0.22. This indicates that no individual panelist was able to consistently detect a difference in flavor or texture resulting from MV drying. Thus, the null hypothesis cannot be rejected.

TABLE V
Brabender Amylograph Peak and Setback Viscosities for Microwave-Vacuum-Dried Rice

	Viscosity (BU)[a]					
		Labelle		Nato		
Drying Code	Starbonnet 1981	1982	1983	1981	1982	1983
Peak viscosity						
MV11	359	423	387	442	532	512
MV12		424	392	443	620	503
MV13		443	395	453	595	504
MV21	374	435	406	518	552	505
MV22		380*[b]	371	455	575	511
MV23		398	381	470	588	507
MV31	356	418	388	460	525*	520
MV32		408	365	458	575	501
MV33	354	393	369	426	533	497
Control	367	434	396	467	582	505
Setback viscosity						
MV11	480	641	537	619	604	523
MV12		647	570	658	650	522
MV13		650	570	644	656	517
MV21	502	640	553	655	661	522
MV22		615	597	620	692	528
MV23		614	589	672	647	526
MV31	494	610	546	608	615	519
MV32		627	581	639	680	525
MV33	495	660	576	653	644	507
Control	480	652	551	660	655	526

[a] Brabender units, measured with a 1,000 cm-g cartridge.
[b] *, Significantly different from the control at $P < 0.05$ (LSD = 51).

TABLE VI
Taste Panel Comparison of Microwave-Vacuum-Dried Samples with the Controls Using the Triangle Test

		Taste Test Evaluations					
		Correctly Identified		Incorrectly Identified		Chi-Square[a]	
Microwave Power (kW/kg)	Dryer Pressure (torr)	Labelle 1982	Nato 1982	Labelle 1982	Nato 1982	Labelle 1982	Nato 1982
0.132	20	3	4	10	11	0.61	0.30
0.264	50	4	4	10	10	0.14	0.14
0.441	60	9	3	12	10	0.86	0.61
0.441	400	3	6	9	12	0.37	0.00
All samples		19	17	41	43	0.08	0.68

[a] Chi-square for a binomial population with a probability of success equal to one-third.

TABLE VII
Ability of Individual Members of the Taste Panel to Identify the Microwave-Dried Samples

	Number of Evaluations		
Panelist	Correct	Incorrect	Random Chance Probability[a]
A	6	12	0.59
B	2	12	0.97
C	6	12	0.59
D	4	10	0.74
E	4	8	0.61
F	4	12	0.83
G	4	6	0.44
H	8	10	0.22

[a] The probability that the panelist would, by random chance only, get a number of correct responses equal to or greater than that shown in the Correct column.

CONCLUSION

There was no evidence to indicate that MV treatments, sufficient to dry green rough rice to safe storage moisture levels, had any adverse effects on the physicochemical properties or eating quality of the resulting milled rice. The cracked kernel explanation for the water-uptake and alkali-spreading changes is speculative and does not eliminate the possibility that changes in starch structure occurred. However, since the variabilities in water-uptake and alkali-spreading values normally found among rice lots with similar cooking and processing characteristics are much greater than the changes caused by the MV-drying treatments, additional research to pinpoint the cause does not seem warranted.

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