Note on Volumetric Reduction of Short Grain Rice During Drying

J. F. STEFFE[1] and R. P. SINGH[2]

ABSTRACT

The shrinkage of white, brown, and rough rice that may occur from commercial drying was estimated from volume measurements taken at high and low grain moisture contents. A 12.3% average volumetric reduction was found for the three types of rice. Data indicate the percent volumetric reduction in the rice hull may be less than that found in other parts of the rough rice kernel.

Cereal Chem. 57(2):148-150

To analyze rice drying, knowledge of the volumetric reduction that may occur as a result of moisture removal is important. Shrinkage is a factor that must be considered when studying stress distribution and moisture movement in rice kernels during drying. Mathematical models that include shrinkage would be a logical extension of existing work on rice cracking (Kunze and Choudhury 1972) and drying (Steffe and Singh 1979a, 1979b).

[1]Assistant Professor of Food Engineering, Department of Agricultural Engineering, Department of Food Science and Human Nutrition, Michigan State University, East Lansing 48824.
[2]Associate Professor of Food Engineering, Department of Agricultural Engineering, Department of Food Science and Technology, University of California, Davis 95616.

0009-0352/80/02014803/$3.00/0

Wratten et al (1969) reported the volume of medium and long grain rough rice at moisture contents ranging from 13.6 to 21.9% dry basis (db). The volume of long grain brown rice has been given for moisture contents from 5.49 to 23.52% db.[3] Various researchers (Kobayashi et al 1972, Morita and Singh 1979) have studied the dimensional changes in rice associated with moisture content variation. Goss (1965) and Kramer (1951) have also measured the physical dimensions of rice. The volumetric reduction in white, brown, and rough rice of the same variety has not been considered.

The objective of this study was to determine the shrinkage that may be encountered by removing water from short grain white (milled), brown, and rough rice. The range of moisture contents found in commercial rice drying was considered.

[3]S. Parasad, J. D. Mannapperuma, and F. T. Wratten. Thermal and hygroscopic expansion of brown rice. Presented at the Southwest Region Meeting of the American Society of Agricultural Engineers. Fountainhead State Park, OK. April 3-4, 1975.

TABLE I
Volumetric Estimates[a] for White, Brown, and Rough Rice

Rice	Test	Initial			Final			Final[b]		
		M	V	N	M	V	N	M	V	N
White	1	29.8	18.3	1040	16.0	16.3	1423	16.0	15.9	1315
	2	29.8	18.4	1194	16.5	16.4	1294	16.5	16.3	1296
	3	30.9	17.5	1188	15.4	15.4	1479	15.5	15.5	1314
	4	31.1	17.5	1176	14.5	15.4	1425	14.4	15.0	1488
	5	31.1	17.6	1298	14.5	15.3	1361	14.3	15.1	1460
Brown	1	28.3	20.4	949	16.2	18.0	1146	16.2	18.0	1062
	2	27.9	20.1	988	16.3	17.7	1023	16.3	18.0	947
	3	28.7	20.4	820	15.3	17.8	861	15.2	17.9	965
	4	28.0	20.0	973	13.6	17.7	1032	13.0	17.3	1237
	5	28.5	20.2	924	13.7	17.6	1007	13.6	17.2	1096
Rough	1	29.4	24.1	648	19.6	22.5	738	19.9	22.3	678
	2	29.3	24.8	770	16.2	22.0	754	16.4	22.0	731
	3	29.7	23.2	749	14.5	21.6	568	14.5	21.3	628
	4	28.9	24.0	737	12.8	21.7	792	12.8	21.6	754
	5	29.4	25.4	708	12.7	21.7	775	12.6	21.6	710

[a]M = Moisture content (percent dry basis), V = volume (mm^3), N = approximate number of kernels.
[b]Replicate.

TABLE II
Estimated Volumes at 30.0 and 15.0% Moisture Content and the Corresponding Volumetric Reductions

Rice	Moisture Content[a] (%)	Estimated Volume (mm^3)	Volumetric Reduction (%)
White	30.0	17.8	
	15.0	15.6	12.4
Brown	30.0	20.5	
	15.0	17.7	13.7
Rough	30.0	24.4	
	15.0	21.8	10.7

[a]Dry basis.

PROCEDURE

All the rice used in this study was S6, a short grain, smooth hulled variety. Rough rice was obtained directly after field harvesting to avoid using rewetted material for data collection. A sufficient quantity of grain was secured so that all experiments could be run from the same sample. The rice, with a moisture content of approximately 31% db, was placed in plastic bags and held at 5° C until needed. To prepare white rice, 300 g of undried rough rice was placed in a Satake huller and the hulls removed. The resulting brown rice was milled for 1.5 min in a Satake rice machine (mill). Numerous trials were run to establish the proper milling time. After 1.5 min, the powder leaving the mill had changed from brown to distinctly white. The goal was to remove the bran completely and leave the starchy endosperm intact; the rice was therefore slightly overmilled. The white rice was held overnight at room temperature before milling. Brown rice samples were prepared from the undried rough rice by adjusting the gap between the rubber rollers on the huller to minimize the damage to the bran layer covering the rice. Unhulled kernels were manually removed from the brown rice, and the material was held overnight at room temperature before testing. Rough rice was simply removed from the cooler and held in the same manner as the brown rice. All samples were kept in moistureproof containers during the holding period.

The general procedures of data collection for white, brown, and rough rice were the same. Samples were removed for moisture content determination and volumetric tests. Volume was measured using an air comparison pycnometer (Beckman). The number of kernels in a sample was determined by finding the average weight of 100 kernels and dividing this number into the total sample weight. The average kernel volume was calculated by dividing the sample volume by the total number of kernels in the sample. The grains were then dried with ambient air to a low moisture content (13.5–16.5% db) and volumetric analysis was conducted on the dried material. An oven drying method (72 hours at 104° C) was used to determine moisture content.

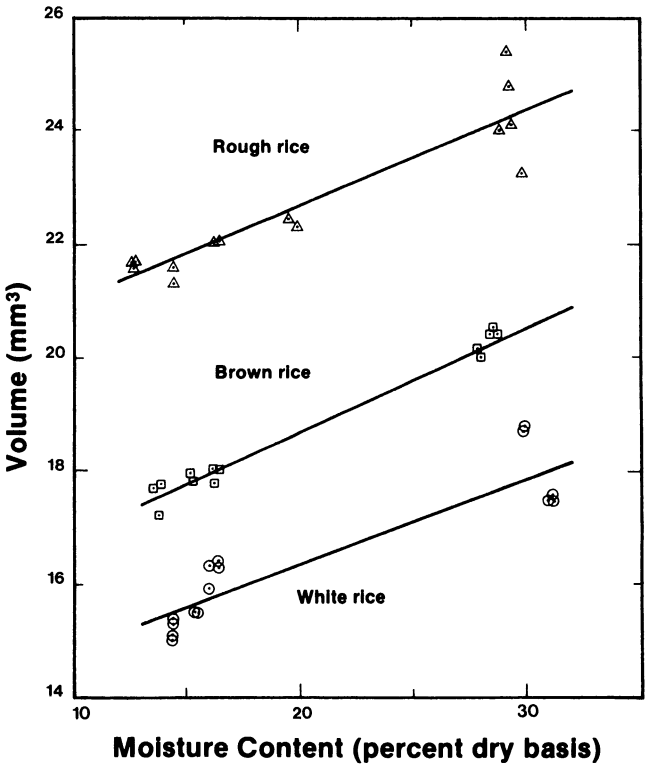

Fig. 1. Volume of white, brown, and rough rice of various moisture contents.

RESULTS AND DISCUSSION

The volumetric measurements calculated for white, brown, and rough rice are presented in Table I. The final samples were taken in duplicate to indicate the repeatability of the experimental procedure. The best straight lines (the true relationship may be curvilinear) drawn through the various data sets suggest similar

TABLE III
Dry Matter Density of Rice Hulls at High and Low Moisture Contents[a]

Test	High Moisture Content		Low Moisture Content	
	Moisture Content[b]	Dry Matter Density (kg/m^3)	Moisture Content[b]	Dry Matter Density (kg/m^3)
1	0.231	1172	0.093	1191
2	0.223	1100	0.079	1178
3	0.240	1188	0.089	1135
4	0.218	1126	0.080	1192
5	0.239	1168	0.091	1145
6	0.222	1094	0.078	1202
Average		1141		1174
Standard deviation		40		27

[a]Data from Steffe 1979.
[b]Decimal dry basis.

volumetric changes in white, brown, and rough rice with changes in moisture content (Fig. 1). These lines were found by regression analysis of the data shown in Table I. The results allow us to make an estimate of the shrinkage that may occur over the range of moisture content found in rice drying. Using estimated kernel volumes at 30 and 15% moisture content (db), the volumetric reduction from drying is found to be 12.4, 13.7, and 10.7% for white, brown, and rough rice, respectively (Table II). The three types of rice averaged 12.3% volumetric reduction.

A number of points about the rice hull must be considered. First, the rough rice volume was measured with an air comparison pycnometer. Close examination of the rough rice kernel reveals an airspace between the hull and bran located principally in the tip of the kernel. The airspace may not be included in the pycnometer's volumetric measurement. This could result in an underestimate of rough rice volume. Second, the volumetric reduction of the hull itself must be considered. The estimated percent volumetric reduction was smallest for rough rice (Table II). A possible explanation for this is that hull shrinkage is proportionately less than shrinkage of the remaining parts of the rough rice kernel. This contention is supported by data reported in Table III. The dry matter density of rice hulls at high and low moisture content was measured. Statistical analysis of these data indicates that the average dry matter density at high moisture content is equal to that at low moisture content; the dry matter was not destroyed or removed in any way during the experiments. Thus, the rice hull will undergo minimal shrinkage (over the range of moisture contents considered) during drying. The airspace between the hull and the inner kernel of rough rice may become progressively larger as drying proceeds.

CONCLUSIONS

The percent volumetric reductions that may be expected in drying white, brown, and rough rice from 30 to 15% moisture content (db) are 12.4, 13.7, and 10.7, respectively. In the shrinkage of rough rice during drying, the volumetric reduction of the hull may be significantly less than that of the remaining portions of the kernel.

LITERATURE CITED

GOSS, J. R. 1965. Some physical properties of forage and cereal crop seed. Am. Soc. Agric. Eng. Paper 65-813.

KOBAYASHI, H., MIWA, Y., and HAYAKAWA, K. 1972. On the mechanism of the cracking in rice kernels during drying of paddies. Res. Bull. Fac. Agric. Gifu Univ. 33:279.

KRAMER, H. A. 1951. Physical dimensions of rice. Agric. Eng. 32:544.

KUNZE, O. R., and CHOUDHURY, M. S. U. 1972. Moisture adsorption related to the tensile strength of rice. Cereal Chem. 49:684.

MORITA, T., and SINGH, R. P. 1979. Physical and thermal properties of short grain rough rice. Trans. ASAE 22:630.

STEFFE, J. F. 1979. Moisture diffusion and tempering in the drying of rough rice. Ph.D. thesis. Department of Agricultural Engineering, University of California, Davis.

STEFFE, J. F., and SINGH, R. P. 1979a. Liquid diffusivity of rough rice components. Am. Soc. Agric. Eng. Paper 79-6005.

STEFFE, J. F., and SINGH, R. P. 1979b. Rough rice tempering. Am. Soc. Agric. Eng. Paper 79-3548.

WRATTEN, F. T., POOLE, W. D., CHESNESS, J. L., BAL, S., and REMARAO, V. V. 1969. Physical and thermal properties of rough rice. Trans ASAE 12:801.

[Received August 22, 1979. Accepted December 13, 1979]