ADSORPTION EQUILIBRIUM MOISTURE CONTENTS OF LONG-GRAIN ROUGH RICE

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ABSTRACT

The effects of temperature, relative humidity, and initial moisture content on equilibrium moisture content of long-grain rough rice under adsorptive conditions were investigated. Air temperatures of 12.5, 15, 20, and 30° C, relative humidities of 70, 80, and 90%, and initial moisture contents ranging from approximately 9% to 15% w.b. were used to obtain equilibrium moisture content data. For a given air condition, equilibrium moisture content varied linearly with initial moisture content. A difference of one percentage point in equilibrium moisture content was measured when rice samples at initial moisture contents of 9% and 15.5% were equilibrated to an air condition of 30° C and 90% relative humidity. Equations were developed to relate equilibrium moisture content to initial moisture content, temperature and relative humidity. The Modified Henderson and Chung equations were modified to include the contribution of initial moisture content in predicting equilibrium moisture content.

INTRODUCTION

The importance of equilibrium moisture content (EMC) data has long been recognized for obtaining conditions during rice drying and storage that are necessary for optimum milling quality. Recent research (Siebenmorgen and Jindal, 1986; Kunze, 1988; Banaszek and Siebenmorgen, 1989a) has shown that detrimental effects to milling quality can be caused by dried rice adsorbing moisture. An initial project was conducted to determine the rate of moisture adsorption by dried rice and the resultant effects on milling quality. Reported in this article are results from that initial project pertaining to the moisture contents (MCs) measured after equilibrium conditions were reached, as well as the results of subsequent tests conducted to investigate the relationship between the initial moisture content (IMC) prior to adsorption and EMC.

LITERATURE REVIEW

Several studies have produced hygroscopic equilibrium values for rough rice and its components. Karon and Adams (1949) presented data on the rate of adsorption and desorption as well as the EMC of rough rice, milled rice, bran and hulls from Rexora variety rice at an IMC of 15.8%*. Saturated salt solutions producing relative humidities (RHs) from 11% to 93% in a static environment at 25° C were used to produce adsorbing and desorbing conditions. Their data indicated that, except for very high and very low RHs, samples suspended above the saturated salt solutions attained equilibrium within three weeks. Hogan and Karon (1955) presented information on EMC of rough rice, but at elevated temperatures. In earlier work, Coleman and Fellows (1925) also reported EMC data for rough rice.

In discussing hysteresis, Young and Nelson (1967) stated that the EMC of a material is not only a function of its immediate environment but is also affected by its previous condition. Hysteresis effects in rough rice have been addressed by Breese (1955) who determined the EMC of rough rice attained over a range of RHs from 10% to 90%. The experiment was conducted with static conditions by placing 2-g samples of short-grain rough rice at MCs of 3.3% and 16.1% above acid and salt solutions at 25° C. Adsorption and desorption curves were reported over a 58-day exposure period. For RHs above 50%, more than 96% of the eventual water uptake took place during the first four days. The results showed that the difference between adsorption and desorption EMCs exceeded 1.5 percentage points from 50% to 70% RH, and was at least one percentage point throughout the 20% to 80% RH range.

Limited research was found addressing the EMCs attained under aerated, non-static conditions with rough rice at different IMCs. Reported herein are EMC data collected under aerated, adsorbing conditions over a range of IMCs.

OBJECTIVES

The objectives were to:

1. Determine the EMC of rough rice, initially at MCs from approximately 9% to 15%, exposed to moisture adsorbing conditions from an airstream at temperature between 12.5° C and 30° C and RHs between 70% and 90%.
2. Compare measured EMC values to reported values calculated by the Modified Henderson and Chung equations.
3. Develop an equation to predict EMC as a function of IMC, temperature, and RH.
4. Modify reported EMC equations to include the effects of IMC under adsorptive conditions for rough rice.

Article was submitted for publication in May 1989; reviewed and approved for publication by the Food and Process Engineering Div. of ASAE in October 1989.

Published with approval of the Director, Arkansas Agricultural Experiment Station, University of Arkansas, Fayetteville.

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* Unless otherwise specified, all references to moisture content are on a wet basis.

Materials and Methods

Newbonnet rice, a long-grain variety, was harvested at the Rice Research and Extension Center, Stuttgart, Arkansas, at approximately 20% MC during September 1987 and stored at 1° C for six months. The rice was dried in 0.21 m^3 (6 bushel) amounts to near the desired MCs of 9.0, 10.5, 12.0, 13.5 and 15.0%. All reported MCs are the average of at least three readings of a Motomco 919A† moisture meter. After drying, all rice was placed back in the 1° C storage until time for testing.

Rice was caused to adsorb moisture by placing 450-g samples in trays in a conditioning chamber. The chamber was built to accommodate 16, 152 by 254 mm (6 x 10 in.) trays with perforated bottoms placed above an air plenum. Air was supplied to the plenum by a RH and temperature control unit (Parameter Generation and Control 300 CFM Climate-Lab-AA). According to manufacturer's specifications, this unit is capable of maintaining RH within ±0.5% and dry-bulb temperature within ±0.2° C. In addition to the monitoring equipment of the control unit, a Phys-Chemical RH and temperature monitoring system was used to mointor air conditions in the plenum below the samples. After air passed through the samples, it was returned to the control unit to form a closed loop system. The total airflow rate was 26.4 L/s (56 cfm) or 1.65 L/s (3.5 cfm) per tray. Two independent but identical control unit/conditioning chamber systems were utilized.

Moisture Adsorption Project Procedure

The experimental design for the moisture adsorption project consisted of moistening rice from approximate MC levels of 9.0, 10.5, 12.0, 13.5, and 15.0% using an airstream at temperatures of 12.5, 20, and 30° C and RHs of 50, 70, and 90%. Samples were removed from the conditioning chamber at 0, 1, 2, 4, 8, 16, 24, 48, 72, 96, 120, 144, and 168 h from the time the samples were placed in the conditioning chamber. The samples were immediately double-bagged in zip-lock plastic storage bags and placed in cold storage. Sample MCs were determined after at least one week in storage. Only the MCs measured after equilibrium conditions were reached are utilized in the analyses reported herein.

A set of moisture adsorption data for the air condition of 30° C and 90% RH is shown in Fig. 1. The trends indicated by the data in this figure represent the responses measured in the other IMC/air condition trials. From Fig. 1 and the other data sets, it was apparent that for the purposes of this study, equilibrium conditions had been reached within 168 h. The data from each IMC/air condition trial were fitted to the following moisture transfer equation given by Page (1949)

$$M = (IMC - EMC) \cdot \exp(-k \cdot t^n) + EMC \qquad (1)$$

where

M	=	moisture content at time t, % wet basis,
IMC	=	initial moisture content, % wet basis,
EMC	=	equilibrium moisture content, % wet basis,
t	=	time, h,
k,n	=	regression coefficients.

† Mention of a commercial name does not imply endorsement by the University of Arkansas.

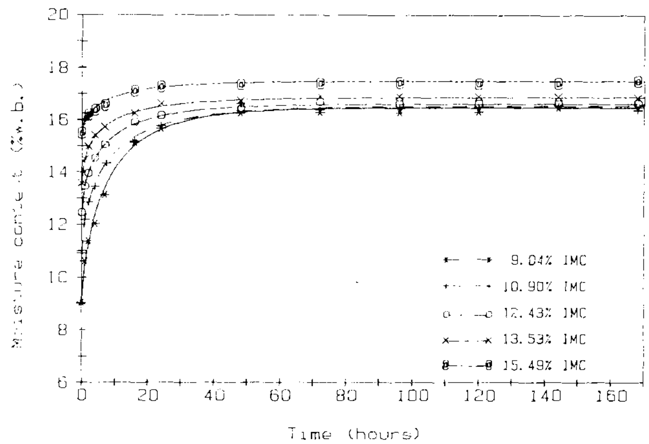

Figure 1-Experimental moisture content data for rough rice exposed to an airstream at 30° C and 90% RH.

The NLIN least squares procedure from SAS (1987) was utilized as a means of statistically determining the asymptotic value (EMC) for each IMC/air condition trial. Complete MC data from this study were reported by Banaszek and Siebenmorgen (1989b).

Subsequent EMC Test Procedure

Investigation of the EMCs attained from the moisture adsorption study revealed that samples of a different IMC did not reach a common asymptotic value for a given air condition. This observation indicated a correlation between IMC and EMC. Thus, additional EMC tests were conducted to further investigate this relationship. Only data relating EMC to IMC were of interest in these tests, whereas in the moisture adsorption project described previously, MC data throughout the entire adsorption process was desired. Because of the long time (approximately one week) required to obtain equilibrated conditions and the objectives of these tests to relate EMC to IMC, the procedure for these tests was modified slightly. Three 450-g samples from each of the five IMC levels used previously were placed in the conditioning unit at a given temperature/RH combination. The samples were removed after 168 hours (1 week) of conditioning and thereafter treated as described for the moisture adsorption project.

The difference in measured EMCs among the samples at each IMC level for these EMC tests ranged from 0.0 to 0.2 percentage points with an average difference of 0.1 percentage points. Thus, due to the small variation in measured EMC values for a given IMC, only the average of the three EMCs for each IMC level was reported.

Due to limited EMC data obtained with low RHs in the moisture adsorption project, tests at combinations of 12.5° C/70% RH, 20° C/70% RH, and 30° C/70% RH were repeated. Also, additional EMC tests were conducted at five new temperature/RH combinations to expand the database for relating EMC to IMC. The five new temperature/RH combinations were 15° C/70%

RH, 15° C/80% RH, 15° C/90% RH, 20° C/80% RH and 30° C/80% RH.

RESULTS AND DISCUSSION

Equilibrium moisture content data from the moisture adsorption project and the subsequent EMC tests were pooled for the analysis. Table 1 lists the air conditions/IMC combinations in which moisture adsorption occurred. Air conditions of 12.5° C/50% RH, 15° C/50% RH and 12.5° C/90% RH were not obtainable with the control units. Also, the desired air condition of 15° C/90% RH was not obtained due to improper control unit settings that resulted in the air condition of 15° C/93% RH.

EFFECT OF IMC ON EMC

A statistical test (Duncan's multiple range test) was calculated with the subsequent EMC test data to determine whether the EMC values obtained for each IMC level at a given air condition were significantly different. The results indicate that for all temperature/RH combinations, the EMC values were all significantly different at a significance level of 5%. This

TABLE 1. Experimental results of EMC tests and comparisons to reported and predicted values

	Condition		MC		%Difference** from Measured EMCs				
Study*	Temp (°C)	RH (dec)	IMC (%w.b.)	EMC (%w.b.)	Regression Eq. 2A	Modified Henderson ASAE, 1987	Remodified Henderson eq. 3	Chung ASAE, 1987	Modified Chung eq. 4
2	12.5	0.70	9.20	12.70	+0.41	-13.05	-0.72	-10.39	-1.06
1			9.81	13.00	+2.12	-10.44	+1.02	-7.84	+0.69
2			10.68	12.80	-0.27	-12.17	-1.39	-9.53	-1.73
1			11.16	13.05	+1.18	-10.02	+0.08	-7.43	-0.25
2			12.52	13.05	-0.14	-10.02	-1.29	-7.43	-1.62
2			13.59	13.66	+3.34	-5.10	+2.18	-2.63	+1.87
2	15	0.70	9.09	12.67	+0.87	-11.80	+0.10	-9.29	-0.30
2			10.51	12.80	+0.48	-10.66	-0.29	-8.18	-0.68
2			12.56	13.00	+0.01	-8.96	-0.81	-6.51	-1.19
2	15	0.80	9.02	14.33	-1.98	-9.35	+0.02	-7.60	+1.33
2			10.53	14.48	-2.24	-8.22	-0.21	-6.49	+1.08
2			12.56	14.60	-3.17	-7.33	-1.14	-5.61	+0.13
2			13.74	14.93	-1.89	-4.96	+0.07	-3.28	+1.31
2	15	0.93	9.02	17.42	+0.71	-6.65	-0.30	-8.85	-0.92
2			10.60	17.56	+0.36	-5.80	-0.52	-7.99	-1.13
2			12.50	17.80	+0.35	-4.38	-0.41	-6.53	-1.01
2			13.59	17.94	+0.36	-3.56	-0.36	-5.70	-0.95
2			15.62	18.12	-0.07	-2.53	-0.75	-4.65	-1.34
2	20	0.70	9.20	12.53	+0.84	-10.19	+0.56	-7.94	+0.08
1			9.48	12.53	+0.56	-10.19	+0.27	-7.94	-0.20
2			10.31	12.62	+0.44	-9.40	+0.15	-7.17	-0.32
1			11.12	12.74	+0.57	-8.37	+0.27	-6.16	-0.20
2			11.38	12.75	+0.39	-8.28	+0.08	-6.07	-0.38
2			12.48	12.89	+0.39	-7.11	+0.03	-4.92	-0.42
2	20	0.80	9.04	14.27	-1.38	-7.08	+0.48	-5.88	+1.57
2			10.66	14.41	-1.82	-6.04	+0.07	-4.85	+1.15
2			12.61	14.55	-2.54	-5.02	-0.66	-3.84	+0.40
2			13.81	14.91	-1.08	-2.49	+0.72	-1.33	+1.75
1	20	0.90	9.15	16.77	+1.34	-3.01	+1.69	-4.51	+1.82
1			9.92	16.65	+0.05	-3.75	+0.45	-5.26	+0.58
1			10.94	16.98	+1.23	-1.73	+1.68	-3.22	+1.81
1			12.43	16.93	-0.18	-2.04	+0.34	-3.52	+0.46
1			13.53	17.12	+0.12	-0.90	+0.65	-2.37	+0.78
1			15.35	17.25	-0.46	-0.14	+0.06	-1.60	+0.19
1	30	0.70	9.12	12.01	-0.88	-9.73	-0.97	-7.85	-1.45
2			9.42	12.01	-1.20	-9.73	-1.29	-7.85	-1.77
2			10.66	12.29	-0.17	-7.23	-0.28	-5.39	-0.75
1			11.04	12.43	+0.57	-6.02	+0.45	-4.20	-0.01
2			12.52	12.69	+1.13	-3.85	+0.94	-2.07	+0.49
2	30	0.80	9.07	14.14	-0.23	-3.23	+0.59	-2.95	+1.45
2			10.71	14.26	-0.85	-2.37	+0.02	-2.09	+0.87
2			12.56	14.45	-1.14	-1.02	-0.29	-0.75	+0.54
2			13.50	14.68	-0.37	+0.56	+0.44	+0.83	+1.26
1	30	0.90	9.04	16.41	+1.08	-0.67	-0.28	-3.63	-0.73
1			10.90	16.52	+0.31	+0.00	-0.92	-2.94	-1.37
1			12.43	16.62	-0.25	+0.60	-1.42	-2.32	-1.86
1			13.53	16.88	+0.47	+2.14	-0.66	-0.75	-1.09
1			15.49	17.44	+2.24	+5.28	+1.15	+2.49	+0.73

Note:
*Study: 1 - Moisture Adsorption Project
2 - Subsequent EMC Tests
**%Difference = [(measured - predicted) / measured] * 100
All moisture content comparisons are on a wet basis

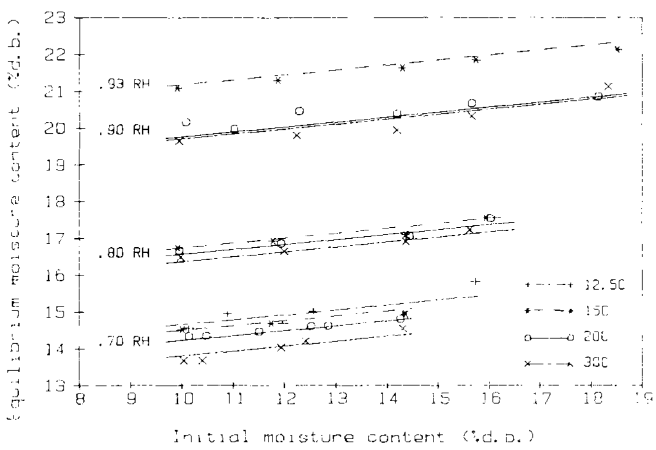

Figure 2-Equilibrium moisture content data and regression curves generated using the Remodified Henderson Equation (Eq. 3).

implies that EMC does depend on IMC under adsorptive conditions.

A plot of EMC vs. IMC for each temperature/RH combination is shown in Fig. 2. The curves shown were produced with the results of equation 3, which is described in a following section. In general, the data show a direct linear relationship between EMC and IMC. The general trend of the data suggests that the relative change in EMC with respect to a change in IMC is constant and is independent of temperature or RH within the temperature and RH limits of the study.

Moisture adsorption by low moisture content rice kernels creates fissures with resultant reductions in head rice yields (Siebenmorgen and Jindal, 1986; Kunze, 1988; Banaszek and Siebenmorgen, 1989a). Head rice yields (HRYs) from the moisture adsorption part of this study were obtained at each sampling time. These HRYs are reported in Banaszek and Siebenmorgen (1989a). The data showed dramatic reductions in HRY only below approximately 12 to 13% IMC. Since Fig. 2 indicates that EMC was linearly proportional to IMC for the full range of IMCs tested (not just below the 12 to 13% IMC level), the cause of the differences in EMC was not entirely attributable to fissures resulting from moisture adsorption.

Comparison of Experimental and Reported EMC Values

The experimental values of EMC along with the associated difference between experimental values and those calculated using the Chung and Modified Henderson equations (ASAE, 1987) are listed in Table 1. All comparisons are made in terms of %MC, wet basis.

Table 1 indicates that the Modified Henderson equation generally produced greater individual differences between experimental and predicted values of EMC than did the Chung equation. The difference between the measured and Modified Henderson values ranged from -13.05 to +5.28% with a mean absolute value of 5.90%. With this equation, the largest differences were found at the 70% RH level while smaller differences were found at the higher RH levels. The differences between experimental values and those calculated by the Chung equation were generally less, ranging from -10.39 to +2.49%, and resulted in a mean absolute difference of 5.18%.

Table 1 shows that in nearly all cases, the Chung and Modified Henderson equations predicted EMC values that were higher than experimental values. This trend can be attributed in large part to hysteresis since the experimental EMCs were obtained under adsorptive conditions and the Chung and Modified Henderson equations were developed using desorptive conditions. Further, Table 1 indicates that for a given air condition, the difference between the measured EMC and either the Modified Henderson or Chung EMC decreased as the IMC increased. Figure 2 explains this trend by showing that for a given air condition, the EMC increased with IMC. This observation represents an extension of the hysteresis effect of grains. Not only are EMC differences produced depending on whether adsorption or desorption has taken place at a given air condition, but also it appears that, at least during adsorption, an auxiliary effect occurs depending on the MC at which adsorption is initiated, which contributes to the amount of hysteresis.

Prediction Equations

Several equations were examined to model the effects of air conditions and IMC on EMC. The first was

$$EMC_w^* = a_1 \cdot IMC_w + b_1 \cdot RH + C_1 \cdot T + d_1 \cdot (RH \cdot T) + e_1 \qquad (2A)$$

where

EMC_w	=	equilibrium moisture content (% wet basis),
IMC_w	=	initial moisture content (% wet basis),
RH	=	relative humidity (decimal),
T	=	temperature (°C),
a_1, b_1, c_1, d_1, e_1	=	regression coefficients.

* The subscripts 'w' and 'd' for the EMC and IMC variables in all reported equations represent % wet and % dry basis, respectively.

A least squares regression procedure (SAS, 1987) was used to fit this equation to the data in a stepwise approach. This technique allowed testing the statistical validity of including each of the variables as a component of a model predicting EMC. The pertinent results of the stepwise regression analysis are shown in Table 2 with the model variables listed in the order in which they were tested for inclusion in the model. It was found that all of the variables of equation [2A] sufficiently improved the model to warrant inclusion in the model at a significance level of 5%. The RH*temperature interaction term was found to be nonsignificant at a significance level of 5%. The model fit the data well with an error mean square (MSE) of 0.035 and a coefficient of multiple determination (R^2) of 0.9916. The following regression results indicate that EMC increases with increases in all variables except temperature:

Coefficients of (2a)	Standard error of estimates
a_1 = 0.12669489	$s(a_1)$ = 0.01512453
b_1 = 20.63328109	$s(b_1)$ = 0.31499144
c_1 = -0.02979736	$s(c_1)$ = 0.00418886
e_1 = -2.58879359	$s(e_1)$ = 0.26488243

TAble 2. Stepwise regression analysis results

Equation 2A

Variables in Model	R^2	MSE
RH	0.9678	0.128
RH, IMC	0.9820	0.073
RH, IMC, T	0.9916	0.035

Equation 2B

Variables in Model	R^2	MSE
RH	0.9661	0.259
RH, IMC	0.9804	0.153
RH, IMC, T	0.9902	0.078

Equation 3

Variables in Model	R^2	MSE
RH*T	0.6557	0.201
RH*T, IMC	0.8981	0.061
RH*T, IMC, T	0.9373	0.038
RH*T, IMC, T, RH	0.9512	0.030

Equation 4

Variables in Model	R^2	MSE
RH*T	0.4221	0.185
RH*T, IMC	0.6607	0.111
RH*T, IMC, RH	0.7906	0.070
RH*T, IMC, RH, T	0.8304	0.058

Note: RH = relative humidity, T = temperature, IMC = initial moisture content

The magnitudes of these coefficients indicate that RH far exceeded temperature and IMC in affecting EMC. Further, a one percentage point change in IMC was equivalent to a 4° C temperature change in affecting EMC.

For the purpose of comparing the form of equation 2A with reported EMC equations that are expressed in dry basis and described in the next section, the IMC and EMC data were converted to dry basis. A least squares regression procedure was used to fit the converted data to an equation analogous to equation 2A:

$$EMC_d = a_2{*}IMC_d + b_2{*}RH + c_2{*}T + d_2{*}(RH{*}T) + e_2 \tag{2B}$$

where a_2, b_2, c_2, d_2, e_2 in the regression coefficients.

The resulting MSE and R^2 for equation 2B were 0.078 and 0.9902, respectively. Again, the RH*temperature term was found to be nonsignificant at a significance level of 5%. The regression coefficients and standard error of estimates for the coefficients of equation 2B were

a_2 = 0.13742478 $s(a_2)$ = 0.01764762
b_2 = 28.52001993 $s(b_2)$ = 0.47332523
c_2 = -0.04152698 $s(c_2)$ = 0.0062851
e_2 = -6.37328978 $s(e_2)$ = 0.38634862

Modification of Existing EMC Equations

The second approach to modeling EMC was to modify existing EMC equations. The two equations chosen to be modified were the Modified Henderson equation and the Chung equation (ASAE, 1987). The Modified Henderson and Chung equations with their respective constants are listed in Table 3. These two equations do not include a term for IMC; thus, a correction equation was added to the models. Since EMC is represented as % dry basis in the Chung and Modified Henderson equations, the experimental data from this study were converted to % dry basis before any regression analysis was performed. A least squares regression procedure from SAS (1987) was utilized to fit the data in a stepwise approach. The Remodified Henderson equation is of the following form:

$$EMC_d = MH + (a_3{*}IMC_d + b_3{*}RH + c_3{*}T + d_3{*}(RH{*}T) + e_3) \tag{3}$$

where MH is the Modified Henderson equation (% dry basis) and a_3, b_3, c_3, d_3, e_3 are the regression coefficients.

The regression coefficients and standard error of estimates for the coefficients of equation 3 were

a_3 = 0.1350716 $s(a_3)$ = 0.01102826
b_3 = -3.23879885 $s(b_3)$ = 0.92819993
c_3 = -0.18547107 $s(c_3)$ = 0.03495854
d_3 = 0.32470421 $s(d_3)$ = 0.04415956
e_3 = -1.72148810 $s(e_3)$ = 0.73981370.

The modified Chung equation is of the form

$$EMC_d = CHUNG + (a_4{*}IMC_d + b_4{*}RH + c_4{*}T + d_4{*}(RH{*}T) + e_4) \tag{4}$$

where CHUNG is the Chung equation (% dry basis) and a_4, b_4, c_4, d_4, e_4 are the regression coefficients.

The regression coefficients and standard error of estimates for the coefficients of equation 4 were

a_4 = 0.13508634 $s(a_4)$ = 0.01523609
b_4 = -6.36933458 $s(b_4)$ = 1.28235472
c_4 = -0.15349309 $s(c_4)$ = 0.04829698
d_4 = 0.26739292 $s(d_4)$ = 0.06100865
e_4 = 1.08788004 $s(e_4)$ = 1.02208971

The results of the stepwise regression analyses for equation 3 and 4 are shown in Table 2 with the model variables listed in the order in which they were tested for inclusion in the model. All model variables and the RH*temperature interaction term in both equations 3 and 4 were significant at a significance level of 5%. The MSE for equations 3 and 4 were 0.030 and 0.058, respectively. The R^2 values for equations 3 and 4 were 0.9512 and 0.8304, respectively. Thus, in terms of MSE, equation 3 is a slightly better overall predictor of adsorptive EMC than either equation 2B or 4 within the temperature and RH limits of the study.

TABLE 3. Modified Henderson and Chung EMC equations with respective constants for rough rice

Modified Henderson equation:

$$EMC = [\ln(1 - RH) / (-k * (T + C))]^{1/N}$$

Constants: $K = 1.9187 * 10^{-5}$, $C = 51.161$, $N = 2.4451$

Chung equation:

$$EMC = [E - F * \ln(-(T + C) * \ln(RH))] * 100$$

Constants: $E = .29394$, $F = .046015$, $C = 35.703$

where EMC = equilibrium moisture content (% dry basis),
RH = relative humidity (decimal),
T = temperature (°C).

Table 1 shows the differences between experimental values of EMC and predicted values of equation 2A, the Remodified Henderson 3 and Modified Chung 4 equations. All comparisons are made in terms of % wet basis. The Remodified Henderson equation produced the smallest range of individual differences, -1.42 to +2.18%, and resulted in the lowest mean absolute difference of 0.61%. The Modified Chung equation produced a slightly larger range of difference, -1.86 to +1.87%, and resulted in a mean absolute difference of 0.94%. Equation 2A resulted in a difference range of -3.17 to +3.34% and a mean absolute difference of 0.92%. There does not appear to be a trend in any of these equations in predicting EMC values that are higher or lower than experimental values at a particular temperature and RH combination.

Summary and Conclusions

Equilibrium moisture contents for long-grain rough rice subjected to adsorptive conditions with initial moisture contents varying from 9 to 15% have been presented to show the effects of IMC, RH and temperature. The results of a Duncan's multiple range test indicated that the EMCs measured for each IMC level for all air conditions were significantly different at a significance level of 5%. The data show RH to be the most significant factor in determining EMC, although IMC and temperature contributed significantly to EMC.

The experimental values of EMC were compared to values predicted by the Chung and Modified Henderson equations. The results indicated that these equations generally predicted EMC values that were higher than the experimental values. Since these equations were developed under desorptive conditions, much of the difference can be attributed to hysteresis.

A regression equation was developed, and two existing EMC equations (Chung and Modified Henderson) were modified to predict the EMC for various air conditions and IMCs. The results of a stepwise regression analysis indicated that the contribution of all variables (IMC, RH, and temperature) was of sufficient significance to warrant inclusion in the models. Based on the regression statistics, the Remodified Henderson equation appears to be the best overall predictor of EMC within the RH and temperature limits of the study.

The data of this study indicate a strong correlation between IMC and EMC at all of the adsorptive air conditions used. This represents an extension of the theory of hysteresis in grains in that not only are EMC differences produced depending on whether equilibrium has been reached through adsorption or desorption, but further, the EMC values, at least during adsorption, were found to depend on IMC. This could have implications not only in explaining differences in measured and reported EMC values but also in understanding the physiological behavior of rice during desorption and adsorption.

Acknowledgment. This research was supported in part by the Arkansas Science and Technology Authority, Little Rock, AR; the Arkansas Rice Research and Promotion Board; and Riceland Foods, Stuttgart, AR.

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