

PP-1111 90
1511 19374

9910786/62

Grain Storage, Processing and Marketing

Research Report No. 18

January 1980

***SOME PROPERTIES
OF CEREAL GRAINS, FOOD LEGUMES
AND OILSEEDS (HYGROSCOPIC,
THERMAL, PHYSICAL) AFFECTING
STORAGE AND DRYING***



**KANSAS
STATE
UNIVERSITY**

**FOOD & FEED GRAIN INSTITUTE
MANHATTAN, KANSAS 66506**

SOME PROPERTIES OF CEREAL GRAINS, FOOD LEGUMES
AND OILSEEDS (HYGROSCOPIC, THERMAL, PHYSICAL)
AFFECTING STORAGE AND DRYING

Prepared by

Gangadhar Rao Vemuganti
Harry B. Pfost
Do Sup Chung
Rosemary Burroughs

Prepared for the

AGENCY FOR INTERNATIONAL DEVELOPMENT
UNITED STATES DEPARTMENT OF STATE

AID/DSAN-CA-0256
Improvement of Postharvest Grain Systems

at the

FOOD AND FEED GRAIN INSTITUTE
Kansas State University
Manhattan, Kansas 66506

Dr. Charles W. Deyoe, Director

TABLE OF CONTENTS

	Page
INTRODUCTION	1
METHODS	2
RESULTS	4
EQUILIBRIUM RELATIVE HUMIDITY, SPECIFIC HEAT AND BULK DENSITY AT VARIOUS MOISTURE CONTENTS FOR:	
Table 1. BARLEY	5
Table 2. BEANS, DRY	6
Table 3. CHICKPEA	7
Table 4. COTTONSEED	8
Table 5. DENT CORN	9
Table 6. FLAXSEED	10
Table 7. FLINT CORN	11
Table 8. LENTIL	12
Table 9. MILLET	13
Table 10. MUNG BEAN	14
Table 11. MUSTARD SEED	15
Table 12. OATS	16
Table 13. PEANUTS	17
Table 14. RAPESEED	18
Table 15. ROUGH RICE (LONG GRAIN)	19
Table 16. ROUGH RICE (MEDIUM GRAIN)	20
Table 17. RYE	21
Table 18. SESAME SEED	22
Table 19. SORGHUM	23
Table 20. SOYBEAN	24

TABLE OF CONTENTS (continued)

	Page
Table 21. SUNFLOWER	25
Table 22. TUVAR (PIGEON PEA) SEED	26
Table 23. WHEAT, DURUM	27
Table 24. WHEAT, HARD	28
Table 25. WHEAT, SOFT	29
REFERENCES	30
APPENDIX	31
Table A. METHODS FOR DETERMINING MOISTURE CONTENT (M.C.) OF WHOLE SEEDS AND CHEMICAL COMPOSITION OF GRAINS, LEGUMES AND OILSEEDS USED	33
Table B. EQUILIBRIUM RELATIVE HUMIDITY CONSTANTS FOR CHUNG-PFOST EQUATION	34
Table C. REGRESSION ANALYSIS OF THE RELATIONSHIP OF SPECIFIC HEAT AND MOISTURE CONTENT	35
Table D. REGRESSION ANALYSIS OF THE RELATIONSHIP OF TEST WEIGHT AND MOISTURE CONTENT	36
Table E. COMPUTER PROGRAM USED FOR GENERATION OF TABLES	37

INTRODUCTION

Knowledge of hygroscopic equilibrium isotherms, heat of desorption or adsorption and bulk density is essential in solving the heat and mass transfer problems involved in grain drying, aeration, storage and processing. Grain moisture content can be easily and quickly measured in grain handling operations. Therefore, tables which list important grain properties in relation to moisture content should prove useful to producers and commercial handlers of grains.

The purposes of this investigation were two-fold: 1) to study equilibrium relative humidities from 10^o-40^oC (50^o-104^oF), specific heat and bulk density in relation to moisture content over the range encountered from harvest to long-term storage for major food grains, food legumes and oilseeds, and 2) to present the data in a convenient form.

Tables were computer generated using appropriate equations developed from experimental data. The numerical values used in the calculations are unique because the measurements for all commodities (except wheat) were made by one investigator using the same methods at the same conditions (1), thus eliminating error factors inherent in using data collected by several laboratories. Because a grain's history affects equilibrium relative humidity, test weight and specific heat, figures in the tables cannot be considered absolute values.

METHODS

The experimental procedures and equations used to obtain the values shown in the tables are described briefly below.

1. Equilibrium relative humidity

Each material was held in desiccators at 30, 50, 70, 80 and 90% relative humidity at 5^o, 10^o, 25^o, 30^o and 40^oC until equilibrium was attained (3-4 weeks). Aqueous sulfuric acid solutions were used to maintain desired relative humidities. Moisture content determinations were made on whole seeds using air-oven methods which are listed in Table A of the Appendix. Also shown on the same table are the proximate chemical analyses for the grain and legume samples used in this research.

The modified Chung-Pfost equation for equilibrium relative humidity (2) was used to generate values shown in the tables.

$$\text{ERH} = \text{EXP} \left[-\frac{A}{R} (T + C) * \text{EXP} (-B * M_D) \right]$$

where A, B, C are constants

$$R = 1.987$$

T = temperature, °C

M_D = moisture content, dry basis (decimal)

ERH = equilibrium relative humidity (decimal)

Constants were estimated using a non-linear least square program, GAUSHAUS (3).

The constants for each crop are shown in Table B of the Appendix.

2. Specific heat

A heat balance equation was used to calculate the specific heat of the various seeds after measuring the temperature rise produced in a known volume (300 ml) of toluene by a quantity of grain (100-300 gm) of a given moisture content with a calorimeter. Measurements were made at five moisture levels between 7-20%, wet basis, at 25^oC.

Values for specific heat were generated from the following equation:

$$C_p = A + B * M$$

where A and B are constants

M = moisture content, wet basis (%)

C_p = specific heat, Btu/lb·°F (Multiply by 4.1868 to obtain kJ/kg·K)

The constants were estimated using the SAS computer program (4) for linear equations. Constants and R² values are shown in Table C of the Appendix.

3. Bulk density

The test weight per bushel (bulk density) of various grains, legumes and oilseeds was measured at five moisture contents (7-20%, wet basis) at 25°C with the standard apparatus recommended by the USDA. The equation below was used to generate the bulk density values.

$$T_w = A + B * M$$

where A and B are constants

M = moisture content, wet basis (%)

T_w = test weight, lbs/bushel (Multiply by 12.8148 to obtain kg/m³)

Regression analysis of the relationship of test weight and moisture content is shown in Table D of the Appendix. Constants were estimated using the SAS program.

4. Computer program

The computer program used for generating values in tables is shown in Table E of the Appendix.

RESULTS

Values for equilibrium relative humidities, specific heat and bulk density at moisture contents ranging from 6% to 28% (w.b.) for 12 cereal grains, five food legumes and 8 oilseeds are tabulated in Tables 1-25.

Table 1. BARLEY: EQUILIBRIUM RELATIVE HUMIDITY, SPECIFIC HEAT AND BULK DENSITY AT VARIOUS MOISTURE CONTENTS

Moisture Content (% w.b.)	Equilibrium Relative Humidity (%)					Specific Heat (kJ/kg·K)	Bulk Density (kg/m ³)
	10 C 50 F	20 C 68 F	25 C 77 F	30 C 86 F	40 C 104 F	25 C 77 F	25 C 77 F
6	9.4	13.5	15.5	17.5	21.4	1.09	636.5
7	14.1	18.5	21.2	23.5	27.7	1.12	632.4
8	19.7	25.2	27.7	30.1	34.6	1.16	627.9
9	26.2	32.1	34.7	37.2	41.7	1.19	623.3
10	33.3	39.3	42.0	44.4	48.8	1.23	618.8
11	40.8	46.6	49.2	51.5	55.6	1.26	614.3
12	48.2	53.8	56.1	58.3	62.0	1.30	609.7
13	55.4	60.5	62.7	64.6	67.9	1.33	605.2
14	62.1	66.7	68.6	70.3	73.2	1.36	600.6
15	68.3	72.3	73.9	75.4	77.9	1.40	596.1
16	73.8	77.2	78.6	79.9	82.0	1.43	591.6
17	78.6	81.5	82.6	83.7	85.4	1.47	587.0
18	82.7	85.1	86.0	86.9	88.3	1.50	582.5
19	86.1	88.1	88.9	89.6	90.7	1.54	578.0
20	89.0	90.6	91.2	91.8	92.7	1.57	573.4
21	91.4	92.6	93.1	93.6	94.3	1.61	568.9
22	93.3	94.3	94.7	95.0	95.6	1.64	564.4
23	94.8	95.6	95.9	96.2	96.6	1.68	559.8
24	96.1	96.6	96.9	97.1	97.4	1.71	555.3
25	97.0	97.5	97.6	97.8	98.0	1.75	550.7
26	97.8	98.1	98.2	98.3	98.5	1.78	546.2
27	98.3	98.6	98.7	98.8	98.9	1.82	541.7
28	98.8	99.0	99.0	99.1	99.2	1.85	537.1

Table 2. BEANS, DRY: BULK DENSITY AT VARIOUS MOISTURE CONTENTS

Moisture Content (% w.b.)	Bulk Density (kg/m ³)			
	Great Northern	Kidney	Lima	Pinto
6	772.6	760.2	724.4	774.2
7	765.6	754.8	721.3	768.1
8	758.5	749.5	718.1	762.0
9	751.4	744.1	715.0	755.9
10	744.4	738.7	711.9	749.8
11	737.3	733.4	708.8	743.7
12	730.2	728.0	705.6	737.6
13	723.2	722.6	702.5	731.5
14	716.1	717.3	699.4	725.3
15	709.0	711.9	696.3	719.2
16	701.9	706.5	693.1	713.1
17	694.9	701.1	690.0	707.0
18	687.8	695.8	686.9	700.9
19	680.7	690.4	683.7	694.8
20	673.7	685.0	680.6	688.7
21	666.6	679.7	677.5	682.6
22	659.5	674.3	674.4	676.4
23	652.4	668.9	671.2	670.3
24	645.4	663.6	668.1	664.2
25	638.3	658.2	665.0	658.1
26	631.2	652.8	661.9	652.0
27	624.2	647.5	658.7	645.9
28	617.1	642.1	655.6	639.8

Table 3. CHICKPEA: EQUILIBRIUM RELATIVE HUMIDITY, SPECIFIC HEAT AND BULK DENSITY AT VARIOUS MOISTURE CONTENTS

Moisture Content (% w.b.)	Equilibrium Relative Humidity (%)					Specific Heat (kJ/kg·K)	Bulk Density (kg/m ³)
	10 C 50 F	20 C 68 F	25 C 77 F	30 C 86 F	40 C 104 F	25 C 77 F	25 C 77 F
6	20.1	22.9	24.2	25.5	28.1	1.20	777.3
7	25.9	28.9	30.3	31.7	34.3	1.23	772.5
8	32.3	35.3	36.8	38.2	40.8	1.27	767.7
9	38.9	41.9	43.4	44.7	47.3	1.30	762.9
10	45.6	48.5	49.9	51.2	53.6	1.34	758.1
11	52.1	54.9	56.2	57.4	59.7	1.37	753.3
12	58.4	61.0	62.2	63.3	65.3	1.40	748.6
13	64.3	66.7	67.7	68.7	70.5	1.44	743.8
14	69.7	71.8	72.7	73.6	75.1	1.47	739.0
15	74.6	76.4	77.2	77.9	79.3	1.50	734.2
16	78.9	80.4	81.1	81.7	82.8	1.54	729.4
17	82.6	83.9	84.4	85.0	85.9	1.57	724.6
18	85.8	86.9	87.3	87.8	88.6	1.60	719.8
19	88.5	89.4	89.8	90.1	90.8	1.64	715.1
20	90.8	91.5	91.8	92.1	92.6	1.67	710.3
21	92.7	93.2	93.5	93.7	94.1	1.70	705.5
22	94.2	94.7	94.9	95.0	95.4	1.74	700.7
23	95.5	95.8	96.0	96.1	96.4	1.77	695.9
24	96.5	96.8	96.9	97.0	97.2	1.80	691.1
25	97.3	97.5	97.6	97.7	97.8	1.84	686.3
26	97.9	98.1	98.2	98.2	98.4	1.87	681.6
27	98.4	98.6	98.6	98.7	98.7	1.90	676.8
28	98.8	98.9	99.0	99.0	99.1	1.94	672.0

Table 4. COTTONSEED: EQUILIBRIUM RELATIVE HUMIDITY, SPECIFIC HEAT AND BULK DENSITY AT VARIOUS MOISTURE CONTENTS

Moisture Content (% w.b.)	Equilibrium Relative Humidity (%)					Specific Heat (kJ/kg·K)	Bulk Density (kg/m ³)
	10 C 50 F	20 C 68 F	25 C 77 F	30 C 86 F	40 C 104 F	25 C 77 F	25 C 77 F
6	24.0	27.3	28.9	30.5	33.4	1.21	620.6
7	31.4	34.9	36.6	38.2	41.1	1.24	612.8
8	39.3	42.8	44.4	46.0	48.8	1.26	604.9
9	47.2	50.6	52.1	53.6	56.2	1.29	597.0
10	54.9	58.0	59.4	60.7	63.1	1.32	589.1
11	62.0	64.8	66.1	67.2	69.3	1.35	581.2
12	68.6	71.0	72.1	73.1	74.9	1.38	573.3
13	74.3	76.4	77.3	78.1	79.6	1.40	565.4
14	79.3	81.0	81.7	82.4	83.7	1.43	557.5
15	83.5	84.9	85.5	86.0	87.0	1.46	549.6
16	86.9	88.1	88.6	89.0	89.8	1.49	541.7
17	89.8	90.7	91.1	91.4	92.1	1.52	533.8
18	92.1	92.8	93.1	93.4	93.9	1.54	525.9
19	94.0	94.5	94.7	95.0	95.3	1.57	518.0
20	95.4	95.8	96.0	96.2	96.5	1.60	510.1
21	96.6	96.9	97.0	97.1	97.3	1.63	502.2
22	97.4	97.7	97.8	97.9	98.0	1.66	494.3
23	98.1	98.3	98.3	98.4	98.5	1.68	486.4
24	98.6	98.7	98.8	98.8	98.9	1.71	478.6
25	99.0	99.1	99.1	99.2	99.2	1.74	470.7
26	99.3	99.3	99.4	99.4	99.4	1.77	462.8
27	99.5	99.5	99.5	99.6	99.6	1.80	454.9
28	99.6	99.7	99.7	99.7	99.7	1.83	447.0

Table 5. DENT CORN: EQUILIBRIUM RELATIVE HUMIDITY, SPECIFIC HEAT AND BULK DENSITY AT VARIOUS MOISTURE CONTENTS

Moisture Content (% w.b.)	Equilibrium Relative Humidity (%)					Specific Heat (kJ/kg·K)	Bulk Density (kg/m ³)
	10 C 50 F	20 C 68 F	25 C 77 F	30 C 86 F	40 C 104 F	25 C 77 F	25 C 77 F
6	11.3	13.3	14.3	15.3	17.3	0.81	779.0
7	17.3	19.7	20.9	22.0	24.3	0.81	772.5
8	24.4	27.1	28.4	29.7	32.1	0.82	765.9
9	32.4	35.3	36.6	37.9	40.4	0.82	759.4
10	40.9	43.7	45.0	46.2	48.6	0.83	752.9
11	49.3	51.9	53.2	54.3	56.5	0.83	746.4
12	57.3	59.7	60.8	61.9	63.8	0.84	739.8
13	64.7	66.8	67.8	68.7	70.4	0.84	733.3
14	71.3	73.1	73.9	74.7	76.1	0.85	726.8
15	76.9	78.5	79.1	79.8	81.0	0.85	720.3
16	81.8	83.0	83.5	84.1	85.0	0.86	713.7
17	85.7	86.7	87.2	87.6	88.3	0.86	707.2
18	89.0	89.8	90.1	90.4	91.0	0.87	700.7
19	91.6	92.2	92.4	92.7	93.2	0.87	694.2
20	93.6	94.1	94.3	94.5	94.8	0.88	687.7
21	95.2	95.6	95.7	95.9	96.1	0.88	681.1
22	96.5	96.7	96.8	96.9	97.1	0.89	674.6
23	97.4	97.6	97.7	97.8	97.9	0.89	668.1
24	98.1	98.2	98.3	98.4	98.5	0.90	661.6
25	98.6	98.7	98.8	98.8	98.9	0.90	655.0
26	99.0	99.1	99.1	99.2	99.2	0.91	648.5
27	99.3	99.4	99.4	99.4	99.4	0.91	642.0
28	99.5	99.6	99.6	99.6	99.6	0.92	635.5

Table 8. LENTIL: EQUILIBRIUM RELATIVE HUMIDITY AND BULK DENSITY AT VARIOUS MOISTURE CONTENTS

Moisture Content (% w.b.)	Equilibrium Relative Humidity (%)					Specific Heat (kJ/kg·K)	Bulk Density (kg/m ³)
	10 C 50 F	20 C 68 F	25 C 77 F	30 C 86 F	40 C 104 F	25 C 77 F	25 C 77 F
6	15.8	17.7	18.7	19.6	21.5		783.3
7	20.8	23.0	24.0	25.1	27.1		774.9
8	26.5	28.8	29.9	31.0	33.1		766.4
9	32.6	35.0	36.2	37.3	39.4		757.9
10	39.0	41.4	42.5	43.6	45.7		749.5
11	45.5	47.8	48.9	49.9	51.9		741.0
12	51.9	54.1	55.1	56.1	57.9		732.6
13	58.0	60.0	61.0	61.9	63.5		724.1
14	63.7	65.6	66.4	67.2	68.7		715.6
15	69.0	70.7	71.4	72.1	73.5		707.2
16	73.0	75.3	75.9	76.5	77.7		698.7
17	76.1	79.3	79.9	80.4	81.4		690.2
18	81.8	82.9	83.3	83.8	84.6		681.8
19	85.1	85.9	86.3	86.7	87.4		673.3
20	87.8	88.5	88.9	89.2	89.8		664.9
21	90.2	90.7	91.0	91.3	91.7		656.4
22	92.1	92.6	92.8	93.0	93.4		647.9
23	93.7	94.1	94.3	94.4	94.7		639.5
24	95.0	95.4	95.5	95.6	95.9		631.0
25	96.1	96.4	96.5	96.6	96.8		622.5
26	97.0	97.2	97.3	97.3	97.5		614.1
27	97.7	97.8	97.9	97.9	98.1		605.6
28	98.2	98.3	98.4	98.4	98.5		597.2

Table 9. MILLET: EQUILIBRIUM RELATIVE HUMIDITY, SPECIFIC HEAT AND BULK DENSITY AT VARIOUS MOISTURE CONTENTS

Moisture Content (% w.b.)	Equilibrium Relative Humidity (%)					Specific Heat (kJ/kg·K)	Bulk Density (kg/m ³)
	10 C 50 F	20 C 68 F	25 C 77 F	30 C 86 F	40 C 104 F	25 C 77 F	25 C 77 F
	6	4.4	6.5	7.6	8.8	11.2	1.11
7	8.7	11.8	13.4	15.0	18.1	1.14	711.7
8	15.0	19.0	21.0	22.9	26.5	1.17	708.7
9	23.1	27.7	29.9	32.0	35.9	1.20	705.7
10	32.4	37.3	39.6	41.7	45.5	1.23	702.6
11	42.3	47.1	49.3	51.3	54.8	1.26	699.6
12	52.1	56.5	58.4	60.2	63.4	1.29	696.6
13	61.1	65.0	66.7	68.2	70.9	1.32	693.5
14	69.2	72.4	73.8	75.1	77.3	1.35	690.5
15	76.0	78.7	79.8	80.8	82.5	1.38	687.5
16	81.6	83.7	84.6	85.4	86.8	1.42	684.5
17	86.2	87.8	88.5	89.1	90.1	1.45	681.4
18	89.7	91.0	91.5	91.9	92.7	1.48	678.4
19	92.5	93.4	93.8	94.1	94.7	1.51	675.4
20	94.5	95.2	95.5	95.7	96.2	1.54	672.3
21	96.1	96.6	96.8	97.0	97.3	1.57	669.3
22	97.2	97.6	97.7	97.8	98.1	1.60	666.3
23	98.1	98.3	98.4	98.5	98.6	1.63	663.3
24	98.7	98.8	98.9	99.0	99.1	1.66	660.2
25	99.1	99.2	99.2	99.3	99.4	1.69	657.2
26	99.4	99.5	99.5	99.5	99.6	1.72	654.2
27	99.6	99.6	99.7	99.7	99.7	1.75	651.1
28	99.7	99.8	99.8	99.8	99.8	1.78	648.1

Table 10. MUNG BEAN: EQUILIBRIUM RELATIVE HUMIDITY, SPECIFIC HEAT AND BULK DENSITY AT VARIOUS MOISTURE CONTENTS

Moisture Content (% w.b.)	Equilibrium Relative Humidity (%)					Specific Heat (kJ/kg·K)	Bulk Density (kg/m ³)
	10 C 50 F	20 C 68 F	25 C 77 F	30 C 86 F	40 C 104 F	25 C 77 F	25 C 77 F
6	3.6	4.0	4.0	4.1	4.2	1.18	868.4
7	13.0	13.2	13.3	13.4	13.7	1.21	857.4
8	28.2	28.5	28.6	28.8	29.1	1.23	846.3
9	45.9	46.2	46.4	46.5	46.8	1.26	835.3
10	62.3	62.6	62.7	62.8	63.1	1.28	824.3
11	75.3	75.5	75.6	75.6	75.8	1.30	813.2
12	84.5	84.6	84.7	84.7	84.8	1.33	802.2
13	90.6	90.7	90.7	90.7	90.8	1.35	791.1
14	94.4	94.5	94.5	94.5	94.6	1.38	780.1
15	96.8	96.8	96.8	96.8	96.9	1.40	769.1
16	98.2	98.2	98.2	98.2	98.2	1.43	758.0
17	99.0	99.0	99.0	99.0	99.0	1.45	747.0
18	99.4	99.4	99.4	99.4	99.4	1.48	735.9
19	99.7	99.7	99.7	99.7	99.7	1.50	724.9
20	99.8	99.8	99.8	99.8	99.8	1.53	713.8
21	99.9	99.9	99.9	99.9	99.9	1.55	702.8
22	****	****	****	****	****	1.58	691.8
23	****	****	****	****	****	1.60	680.7
24	****	****	****	****	****	1.63	669.7
25	****	****	****	****	****	1.65	658.6
26	****	****	****	****	****	1.68	647.6
27	****	****	****	****	****	1.70	636.6
28	****	****	****	****	****	1.72	625.5

Table 11. MUSTARD SEED: EQUILIBRIUM RELATIVE HUMIDITY, SPECIFIC HEAT AND BULK DENSITY AT VARIOUS MOISTURE CONTENTS

Moisture Content (% w.b.)	Equilibrium Relative Humidity (%)					Specific Heat (kJ/kg·K)	Bulk Density (kg/m ³)
	10 C 50 F	20 C 68 F	25 C 77 F	30 C 86 F	40 C 104 F	25 C 77 F	25 C 77 F
	6	30.4	34.4	36.3	38.0	41.3	1.46
7	41.1	45.1	46.9	48.5	51.6	1.49	676.3
8	51.7	55.3	56.9	58.5	61.2	1.52	673.1
9	61.4	64.6	66.0	67.3	69.6	1.55	669.9
10	69.9	72.6	73.7	74.8	76.7	1.58	666.8
11	77.1	79.2	80.1	80.9	82.4	1.61	663.6
12	82.9	84.5	85.2	85.8	87.0	1.64	660.5
13	87.4	88.6	89.1	89.6	90.5	1.66	657.3
14	90.8	91.7	92.1	92.5	93.1	1.69	654.2
15	93.4	94.1	94.4	94.6	95.1	1.72	651.0
16	95.4	95.8	96.0	96.2	96.5	1.75	647.8
17	96.8	97.1	97.2	97.4	97.6	1.78	644.7
18	97.6	98.0	98.1	98.2	98.3	1.81	641.5
19	98.5	98.6	98.7	98.8	98.9	1.84	638.4
20	99.0	99.1	99.1	99.2	99.2	1.87	635.2
21	99.3	99.4	99.4	99.4	99.5	1.90	632.1
22	99.5	99.6	99.6	99.6	99.7	1.92	628.9
23	99.7	99.7	99.7	99.8	99.8	1.95	625.7
24	99.8	99.8	99.8	99.8	99.9	1.98	622.6
25	99.9	99.9	99.9	99.9	99.9	2.01	619.4
26	99.9	99.9	99.9	99.9	99.9	2.04	616.3
27	****	****	****	****	****	2.07	613.1
28	****	****	****	****	****	2.10	610.0

Table 12. OATS: EQUILIBRIUM RELATIVE HUMIDITY, SPECIFIC HEAT AND BULK DENSITY AT VARIOUS MOISTURE CONTENTS

Moisture Content (% w.b.)	Equilibrium Relative Humidity (%)					Specific Heat (kJ/kg·K)	Bulk Density (kg/m ³)
	10 C	20 C	25 C	30 C	40 C	25 C	25 C
	50 F	68 F	77 F	86 F	104 F	77 F	77 F
6	7.5	10.1	11.5	12.9	15.6	0.90	528.0
7	12.3	15.7	17.4	19.0	22.2	1.02	523.2
8	18.5	22.5	24.4	26.3	29.8	1.15	518.4
9	25.8	30.3	32.3	34.3	37.9	1.27	513.6
10	34.0	38.5	40.6	42.6	46.0	1.40	508.8
11	42.5	46.9	48.9	50.8	54.1	1.52	504.0
12	50.9	55.0	56.9	58.6	61.6	1.65	499.2
13	58.8	62.6	64.2	65.7	68.4	1.77	494.4
14	66.1	69.4	70.8	72.1	74.3	1.90	489.6
15	72.5	75.3	76.5	77.6	79.4	2.03	484.8
16	78.1	80.3	81.3	82.2	83.7	2.15	480.0
17	82.7	84.6	85.3	86.0	87.3	2.28	475.2
18	86.5	88.0	88.6	89.2	90.2	2.40	470.4
19	89.6	90.8	91.3	91.7	92.5	2.53	465.6
20	92.1	93.0	93.4	93.7	94.3	2.65	460.8
21	94.1	94.7	95.0	95.3	95.7	2.78	456.0
22	95.6	96.1	96.3	96.5	96.8	2.90	451.2
23	96.7	97.1	97.3	97.4	97.6	3.03	446.4
24	97.6	97.9	98.0	98.1	98.3	3.16	441.6
25	98.3	98.5	98.5	98.6	98.8	3.28	436.8
26	98.8	98.9	99.0	99.0	99.1	3.41	432.0
27	99.1	99.2	99.3	99.3	99.4	3.53	427.2
28	99.4	99.4	99.5	99.5	99.6	3.66	422.4

Table 13. PEANUTS: EQUILIBRIUM RELATIVE HUMIDITY, SPECIFIC HEAT AND BULK DENSITY AT VARIOUS MOISTURE CONTENTS

Moisture Content (% w.b.)	Equilibrium Relative Humidity (%)					Specific Heat (kJ/kg·K)	Bulk Density (kg/m ³)
	10 C 50 F	20 C 68 F	25 C 77 F	30 C 86 F	40 C 104 F	25 C 77 F	25 C 77 F
6	50.9	54.7	56.5	58.1	60.9	1.37	629.6
7	62.1	65.4	66.8	68.2	70.5	1.41	627.5
8	71.7	74.3	75.4	76.5	78.3	1.46	625.5
9	79.4	81.4	82.2	83.0	84.4	1.50	623.4
10	85.3	86.8	87.4	88.0	89.0	1.55	621.4
11	89.7	90.8	91.2	91.6	92.3	1.59	619.3
12	92.9	93.7	94.0	94.3	94.8	1.64	617.3
13	95.2	95.7	95.9	96.1	96.5	1.68	615.2
14	96.8	97.1	97.3	97.4	97.6	1.72	613.2
15	97.9	98.1	98.2	98.3	98.4	1.77	611.1
16	98.6	98.8	98.8	98.9	99.0	1.81	609.1
17	99.1	99.2	99.2	99.3	99.3	1.86	607.0
18	99.4	99.5	99.5	99.5	99.6	1.90	605.0
19	99.6	99.7	99.7	99.7	99.7	1.95	602.9
20	99.8	99.8	99.8	99.8	99.8	1.99	600.9
21	99.9	99.9	99.9	99.9	99.9	2.04	598.8
22	99.9	99.9	99.9	99.9	99.9	2.08	596.8
23	99.9	****	****	****	****	2.13	594.7
24	****	****	****	****	****	2.17	592.7
25	****	****	****	****	****	2.22	590.6
26	****	****	****	****	****	2.26	588.6
27	****	****	****	****	****	2.31	586.5
28	****	****	****	****	****	2.35	584.5

Table 14. RAPESEED: EQUILIBRIUM RELATIVE HUMIDITY, SPECIFIC HEAT AND BULK DENSITY AT VARIOUS MOISTURE CONTENTS

Moisture Content (% w.b.)	Equilibrium Relative Humidity (%)					Specific Heat (kJ/kg·K)	Bulk Density (kg/m ³)
	10 C 50 F	20 C 68 F	25 C 77 F	30 C 86 F	40 C 104 F	25 C 77 F	25 C 77 F
6	40.3	43.1	44.4	45.7	48.0	1.44	662.8
7	51.8	54.4	55.6	56.7	58.8	1.48	659.7
8	62.3	64.5	65.5	66.5	68.3	1.51	656.6
9	71.4	73.2	74.0	74.7	76.1	1.54	653.5
10	78.7	80.1	80.8	81.4	82.4	1.58	650.4
11	84.5	85.6	86.1	86.5	87.3	1.61	647.3
12	88.9	89.7	90.1	90.4	91.0	1.64	644.2
13	92.2	92.8	93.0	93.2	93.7	1.67	641.1
14	94.6	95.0	95.2	95.3	95.6	1.71	638.0
15	96.3	96.6	96.7	96.8	97.0	1.74	634.9
16	97.5	97.7	97.8	97.8	98.0	1.77	631.8
17	98.3	98.4	98.5	98.5	98.6	1.81	628.7
18	98.9	99.0	99.0	99.0	99.1	1.84	625.6
19	99.3	99.3	99.3	99.4	99.4	1.87	622.
20	99.5	99.6	99.6	99.6	99.6	1.91	619.4
21	99.7	99.7	99.7	99.7	99.8	1.94	616.3
22	99.8	99.8	99.8	99.8	99.8	1.97	613.2
23	99.9	99.9	99.9	99.9	99.9	2.01	610.1
24	99.9	99.9	99.9	99.9	99.9	2.04	607.0
25	****	****	****	****	****	2.07	603.9
26	****	****	****	****	****	2.10	600.8
27	****	****	****	****	****	2.14	597.7
28	****	****	****	****	****	2.17	594.6

Table 15. ROUGH RICE (LONG GRAIN): EQUILIBRIUM RELATIVE HUMIDITY AT VARIOUS MOISTURE CONTENTS

Moisture Content (% w.b.)	Equilibrium Relative Humidity (%)					Specific Heat (kJ/kg·K)	Bulk Density (kg/m ³)
	10 C 50 F	20 C 68 F	25 C 77 F	30 C 86 F	40 C 104 F	25 C 77 F	25 C 77 F
6	6.9	9.6	11.0	12.4	15.2		
7	11.9	15.5	17.2	18.9	22.3		
8	18.5	22.8	24.8	26.8	30.5		
9	26.5	31.2	33.3	35.4	39.2		
10	35.3	40.1	42.3	44.3	48.0		
11	44.4	49.0	51.1	53.0	56.4		
12	53.3	57.5	59.4	61.1	64.1		
13	61.5	65.3	66.9	68.4	71.0		
14	68.9	72.2	73.5	74.8	76.9		
15	75.3	78.0	79.1	80.1	81.9		
16	80.7	82.9	83.8	84.6	86.0		
17	85.1	86.8	87.5	88.2	89.3		
18	88.7	90.0	90.5	91.0	91.9		
19	91.5	92.5	92.9	93.3	93.9		
20	93.7	94.4	94.7	95.0	95.5		
21	95.3	95.9	96.1	96.3	96.7		
22	96.6	97.0	97.2	97.3	97.6		
23	97.6	97.8	98.0	98.1	98.3		
24	98.3	98.5	98.6	98.6	98.8		
25	98.8	98.9	99.0	99.0	99.1		
26	99.1	99.2	99.3	99.3	99.4		
27	99.4	99.5	99.5	99.5	99.6		
28	99.6	99.6	99.7	99.7	99.7		

Table 16. ROUGH RICE (MEDIUM GRAIN): EQUILIBRIUM RELATIVE HUMIDITY, SPECIFIC HEAT AND BULK DENSITY AT VARIOUS MOISTURE CONTENTS

Moisture Content (% w.b.)	Equilibrium Relative Humidity (%)					Specific Heat (kJ/kg·K)	Bulk Density (kg/m ³)
	10 C 50 F	20 C 68 F	25 C 77 F	30 C 86 F	40 C 104 F		
6	4.3	6.0	7.0	7.9	10.0	1.24	592.0
7	8.5	11.1	12.4	13.7	16.4	1.26	596.1
8	14.6	18.0	19.7	21.3	24.5	1.28	600.2
9	22.5	26.5	28.3	30.2	33.6	1.29	604.3
10	31.7	35.9	37.9	39.7	43.1	1.31	608.5
11	41.4	45.6	47.5	49.3	52.5	1.33	612.6
12	51.1	55.0	56.7	58.3	61.2	1.35	616.7
13	60.2	63.6	65.1	66.5	69.0	1.36	620.8
14	68.3	71.2	72.4	73.6	75.6	1.38	625.0
15	75.2	77.6	78.6	79.5	81.2	1.40	629.1
16	80.9	82.8	83.6	84.4	85.7	1.42	633.2
17	85.6	87.1	87.7	88.2	89.2	1.44	637.3
18	89.2	90.4	90.8	91.3	92.0	1.45	641.5
19	92.1	92.9	93.3	93.6	94.1	1.47	645.6
20	94.2	94.8	95.1	95.3	95.8	1.49	649.7
21	95.9	96.3	96.5	96.7	97.0	1.51	653.8
22	97.0	97.4	97.5	97.6	97.8	1.52	658.0
23	97.9	98.1	98.2	98.3	98.5	1.54	662.1
24	98.6	98.7	98.8	98.8	98.9	1.56	666.2
25	99.0	99.1	99.2	99.2	99.3	1.58	670.4
26	99.3	99.4	99.4	99.5	99.5	1.59	674.5
27	99.5	99.6	99.6	99.6	99.7	1.61	678.6
28	99.7	99.7	99.7	99.8	99.8	1.63	682.7

Table 17. RYE: EQUILIBRIUM RELATIVE HUMIDITY, SPECIFIC HEAT AND BULK DENSITY AT VARIOUS MOISTURE CONTENTS

Moisture Content (% w.b.)	Equilibrium Relative Humidity (%)					Specific Heat (kJ/kg·K)	Bulk Density (kg/m ³)
	10 C 50 F	20 C 68 F	25 C 77 F	30 C 86 F	40 C 104 F	25 C 77 F	25 C 77 F
6	7.1	8.3	8.9	9.5	10.8	1.28	767.6
7	11.4	13.0	13.8	14.6	16.1	1.32	757.5
8	17.0	18.9	19.8	20.7	22.5	1.36	747.4
9	23.7	25.8	26.9	27.8	29.8	1.40	737.3
10	31.3	33.5	34.5	35.6	37.5	1.44	727.2
11	39.2	41.4	42.5	43.5	45.4	1.48	717.1
12	47.2	49.4	50.4	51.3	53.2	1.52	707.0
13	55.0	57.0	57.9	58.8	60.4	1.56	696.9
14	62.3	64.0	64.8	65.6	67.1	1.60	686.8
15	68.8	70.3	71.1	71.7	73.0	1.64	676.6
16	74.6	75.9	76.5	77.1	78.1	1.68	666.5
17	79.6	80.7	81.2	81.6	82.5	1.72	656.4
18	83.8	84.7	85.1	85.4	86.2	1.76	646.3
19	87.3	88.0	88.3	88.6	89.2	1.80	636.2
20	90.1	90.7	90.9	91.2	91.6	1.85	626.1
21	92.4	92.8	93.0	93.2	93.5	1.89	616.0
22	94.2	94.5	94.7	94.8	95.1	1.93	605.9
23	95.6	95.9	96.0	96.1	96.3	1.97	595.8
24	96.7	96.9	97.0	97.1	97.2	2.01	585.6
25	97.6	97.7	97.8	97.8	98.0	2.05	575.5
26	98.2	98.3	98.4	98.4	98.5	2.09	565.4
27	98.7	98.8	98.8	98.9	98.9	2.13	555.3
28	99.1	99.1	99.1	99.2	99.2	2.17	545.2

Table 19. SORGHUM: EQUILIBRIUM RELATIVE HUMIDITY, SPECIFIC HEAT AND BULK DENSITY AT VARIOUS MOISTURE CONTENTS

Moisture Content (% w.b.)	Equilibrium Relative Humidity (%)					Specific Heat (kJ/kg·K)	Bulk Density (kg/m ³)
	10 C 50 F	20 C 68 F	25 C 77 F	30 C 86 F	40 C 104 F	25 C 77 F	25 C 77 F
6	6.4	8.9	10.2	11.6	14.3	1.15	786.9
7	10.8	14.2	15.9	17.5	20.8	1.17	782.9
8	16.7	20.8	22.8	24.7	28.3	1.20	778.7
9	23.9	28.5	30.6	32.7	36.4	1.23	774.6
10	32.0	36.8	39.0	41.0	44.8	1.25	770.4
11	40.6	45.3	47.4	49.4	52.9	1.28	766.3
12	49.2	53.6	55.6	57.4	60.6	1.30	762.2
13	57.3	61.4	63.1	64.7	67.5	1.33	758.1
14	64.8	68.4	69.9	71.3	73.7	1.36	753.9
15	71.5	74.5	75.8	76.9	78.9	1.38	749.8
16	77.3	79.7	80.8	81.7	83.3	1.41	745.7
17	82.1	84.1	84.9	85.7	87.0	1.44	741.6
18	86.1	87.7	88.3	88.9	90.0	1.46	737.4
19	89.3	90.5	91.1	91.5	92.3	1.49	733.3
20	91.9	92.8	93.2	93.6	94.2	1.52	729.2
21	93.9	94.6	94.9	95.2	95.6	1.54	725.1
22	95.5	96.0	96.2	96.4	96.8	1.57	721.0
23	96.6	97.1	97.2	97.4	97.6	1.59	716.8
24	97.6	97.8	98.0	98.1	98.3	1.62	712.7
25	98.2	98.4	98.5	98.6	98.7	1.65	708.6
26	98.7	98.9	99.0	99.0	99.1	1.67	704.5
27	99.1	99.2	99.3	99.3	99.4	1.70	700.3
28	99.4	99.4	99.5	99.5	99.6	1.73	696.2

Table 20. SOYBEAN: EQUILIBRIUM RELATIVE HUMIDITY, SPECIFIC HEAT AND BULK DENSITY AT VARIOUS MOISTURE CONTENTS

Moisture Content (% w.b.)	Equilibrium Relative Humidity (%)					Specific Heat (kJ/kg·K)	Bulk Density (kg/m ³)
	10 C 50 F	20 C 68 F	25 C 77 F	30 C 86 F	40 C 104 F	25 C 77 F	25 C 77 F
6	30.1	32.6	33.8	34.9	37.1	1.27	720.4
7	35.5	38.0	39.2	40.4	42.5	1.30	716.6
8	41.1	43.5	44.7	45.8	48.0	1.33	712.9
9	46.6	49.0	50.2	51.2	53.3	1.35	709.2
10	52.1	54.4	55.5	56.5	58.4	1.38	705.4
11	57.5	59.6	60.6	61.5	63.3	1.40	701.7
12	62.5	64.5	65.4	66.2	67.8	1.43	697.9
13	67.2	69.0	69.8	70.6	72.1	1.45	694.2
14	71.6	73.2	73.9	74.6	75.9	1.48	690.4
15	75.6	77.0	77.6	78.3	79.4	1.50	686.7
16	79.2	80.4	81.0	81.5	82.5	1.53	683.0
17	82.4	83.4	83.9	84.4	85.2	1.56	679.2
18	85.2	86.1	86.5	86.9	87.6	1.58	675.5
19	87.6	88.4	88.7	89.1	89.7	1.61	671.7
20	89.8	90.4	90.7	91.0	91.5	1.63	668.0
21	91.6	92.1	92.3	92.6	93.0	1.66	664.3
22	93.1	93.5	93.7	93.9	94.3	1.68	660.5
23	94.4	94.8	94.9	95.1	95.4	1.71	656.8
24	95.5	95.8	95.9	96.0	96.3	1.73	653.0
25	96.4	96.6	96.7	96.8	97.0	1.76	649.3
26	97.1	97.3	97.4	97.5	97.6	1.79	645.5
27	97.7	97.9	97.9	98.0	98.1	1.81	641.8
28	98.2	98.3	98.4	98.4	98.5	1.84	638.1

Table 21. SUNFLOWER: EQUILIBRIUM RELATIVE HUMIDITY, SPECIFIC HEAT AND BULK DENSITY AT VARIOUS MOISTURE CONTENTS

Moisture Content (% w.b.)	Equilibrium Relative Humidity (%)					Specific Heat (kJ/kg·K)	Bulk Density (kg/m ³)
	10 C 50 F	20 C 68 F	25 C 77 F	30 C 86 F	40 C 104 F	25 C 77 F	25 C 77 F
6	31.9	35.3	36.9	38.5	41.3	1.37	337.7
7	41.9	45.3	46.8	48.3	51.0	1.40	335.3
8	51.8	54.9	56.3	57.6	60.1	1.43	332.9
9	60.9	63.7	64.9	66.1	68.2	1.47	330.5
10	69.0	71.4	72.4	73.3	75.1	1.50	328.1
11	75.9	77.8	78.7	79.4	80.8	1.53	325.6
12	81.6	83.1	83.8	84.4	85.5	1.56	323.2
13	86.2	87.3	87.8	88.3	89.1	1.59	320.8
14	89.7	90.6	91.0	91.3	92.0	1.63	318.4
15	92.5	93.1	93.4	93.7	94.1	1.66	316.0
16	94.6	95.0	95.2	95.4	95.8	1.69	313.6
17	96.1	96.4	96.6	96.7	97.0	1.72	311.2
18	97.2	97.5	97.6	97.7	97.9	1.75	308.8
19	98.1	98.2	98.3	98.4	98.5	1.78	306.4
20	98.7	98.8	98.8	98.9	99.0	1.82	304.0
21	99.1	99.2	99.2	99.2	99.3	1.85	301.6
22	99.4	99.4	99.4	99.5	99.5	1.88	299.1
23	99.6	99.6	99.6	99.6	99.7	1.91	296.7
24	99.7	99.7	99.8	99.8	99.8	1.94	294.3
25	99.8	99.8	99.8	99.8	99.9	1.98	291.9
26	99.9	99.9	99.9	99.9	99.9	2.01	289.5
27	99.9	99.9	99.9	99.9	99.9	2.04	287.1
28	****	****	****	****	****	2.07	284.7

Table 22. TUVAR (PIGEON PEA) SEED: EQUILIBRIUM RELATIVE HUMIDITY, SPECIFIC HEAT AND BULK DENSITY AT VARIOUS MOISTURE CONTENTS

Moisture Content (% w.b.)	Equilibrium Relative Humidity (%)					Specific Heat (kJ/kg·K)	Bulk Density (kg/m ³)
	10 C 50 F	20 C 68 F	25 C 77 F	30 C 86 F	40 C 104 F	25 C 77 F	25 C 77 F
6	16.2	17.7	18.5	19.2	20.7	1.30	824.8
7	21.4	23.1	23.9	24.8	26.4	1.32	820.7
8	27.3	29.1	30.0	30.8	32.5	1.34	816.7
9	33.6	35.5	36.4	37.2	39.0	1.37	812.7
10	40.1	42.0	42.9	43.8	45.5	1.39	808.6
11	46.8	48.6	49.4	50.3	51.8	1.42	804.6
12	53.2	54.9	55.7	56.5	58.0	1.44	800.5
13	59.4	61.0	61.7	62.4	63.8	1.47	796.5
14	65.1	66.6	67.2	67.9	69.1	1.49	792.4
15	70.4	71.7	72.2	72.8	73.9	1.51	788.4
16	75.1	76.2	76.7	77.2	78.1	1.54	784.3
17	79.3	80.2	80.7	81.1	81.9	1.56	780.3
18	83.0	83.7	84.1	84.4	85.1	1.59	776.2
19	86.1	86.7	87.0	87.3	87.8	1.61	772.2
20	88.7	89.3	89.5	89.7	90.2	1.64	768.1
21	90.9	91.4	91.6	91.8	92.1	1.66	764.1
22	92.8	93.1	93.3	93.4	93.7	1.68	760.0
23	94.3	94.6	94.7	94.8	95.1	1.71	756.0
24	95.5	95.8	95.9	95.9	96.1	1.73	751.9
25	96.5	96.7	96.8	96.9	97.0	1.76	747.9
26	97.3	97.5	97.5	97.6	97.7	1.78	743.8
27	97.9	98.1	98.1	98.1	98.2	1.81	739.8
28	98.4	98.5	98.6	98.6	98.7	1.83	735.7

Table 24. WHEAT, HARD: EQUILIBRIUM RELATIVE HUMIDITY, SPECIFIC HEAT AND BULK DENSITY AT VARIOUS MOISTURE CONTENTS

Moisture Content (% w.b.)	Equilibrium Relative Humidity (%)					Specific Heat (kJ/kg·K)	Bulk Density (kg/m ³)
	10 C 50 F	20 C 68 F	25 C 77 F	30 C 86 F	40 C 104 F	25 C 77 F	25 C 77 F
6	24.2	29.5	32.0	34.3	38.6	1.37	1427.7
7	31.3	36.9	39.4	41.7	45.9	1.40	1425.1
8	38.9	44.4	46.9	49.1	53.1	1.43	1422.4
9	46.5	51.8	54.1	56.2	59.9	1.46	1419.8
10	53.9	58.8	60.9	62.8	66.1	1.49	1417.2
11	60.9	65.3	67.2	68.9	71.7	1.52	1414.6
12	67.3	71.2	72.8	74.2	76.7	1.55	1412.0
13	73.0	76.3	77.7	78.9	81.0	1.58	1409.4
14	78.0	80.8	81.9	82.9	84.7	1.61	1406.8
15	82.3	84.6	85.5	86.3	87.7	1.64	1404.2
16	85.8	87.7	88.5	89.1	90.3	1.67	1401.6
17	88.8	90.3	90.9	91.5	92.4	1.70	1399.0
18	91.3	92.4	92.9	93.3	94.1	1.73	1396.3
19	93.2	94.1	94.5	94.9	95.4	1.76	1393.7
20	94.8	95.5	95.8	96.1	96.5	1.79	1391.1
21	96.0	96.6	96.8	97.0	97.3	1.82	1388.5
22	97.0	97.4	97.6	97.7	98.0	1.85	1385.9
23	97.8	98.1	98.2	98.3	98.5	1.88	1383.3
24	98.3	98.6	98.7	98.7	98.9	1.91	1380.7
25	98.8	98.9	99.0	99.1	99.2	1.94	1378.1
26	99.1	99.2	99.3	99.3	99.4	1.97	1375.5
27	99.4	99.4	99.5	99.5	99.6	2.00	1372.9
28	99.5	99.6	99.6	99.7	99.7	2.03	1370.2

Table 25. WHEAT, SOFT: EQUILIBRIUM RELATIVE HUMIDITY AND SPECIFIC HEAT AT VARIOUS MOISTURE CONTENTS

Moisture Content (% w.b.)	Equilibrium Relative Humidity (%)					Specific Heat (kJ/kg·K)	Bulk Density (kg/m ³)
	10 C 50 F	20 C 68 F	25 C 77 F	30 C 86 F	40 C 104 F	25 C 77 F	25 C 77 F
6	17.0	23.3	26.3	29.1	34.3	1.64	
7	25.8	32.9	36.1	39.0	44.2	1.68	
8	35.8	43.0	46.1	48.9	53.8	1.72	
9	46.1	52.9	55.8	58.3	62.6	1.76	
10	55.9	62.1	64.6	66.8	70.4	1.80	
11	64.9	70.1	72.2	74.0	77.0	1.85	
12	72.6	76.9	78.6	80.0	82.4	1.89	
13	79.0	82.5	83.8	84.9	86.8	1.93	
14	84.2	86.9	87.9	88.8	90.2	1.97	
15	88.3	90.3	91.1	91.7	92.8	2.01	
16	91.5	92.9	93.5	94.0	94.8	2.05	
17	93.8	94.9	95.3	95.7	96.2	2.09	
18	95.6	96.4	96.7	96.9	97.3	2.13	
19	96.9	97.4	97.7	97.8	98.1	2.17	
20	97.8	98.2	98.4	98.5	98.7	2.21	
21	98.5	98.8	98.9	99.0	99.1	2.25	
22	99.0	99.2	99.2	99.3	99.4	2.29	
23	99.3	99.4	99.5	99.5	99.6	2.33	
24	99.5	99.6	99.7	99.7	99.7	2.37	
25	99.7	99.7	99.8	99.8	99.8	2.41	
26	99.8	99.8	99.8	99.9	99.9	2.45	
27	99.9	99.9	99.9	99.9	99.9	2.49	
28	99.9	99.9	99.9	99.9	****	2.54	

REFERENCES

- Vemuganti, G. 1980. Grain properties affecting storage and drying. Ph.D. Dissertation, Kansas State University, Manhattan 66506.
- Chung, D. S. and H. B. Pfoest. 1967. Adsorption and desorption of water vapor by cereal grains and their products. Trans. of the ASAE 10(4): 549-557.
- Wood, F. S. and H. W. Nelson. 1969. Non-linear least squares curve multiple regression analysis (GAUSHAUS), a computer program in FORTRAN IV language. I.B.M. Share Library, Distribution-13, No. 3600-13.6.007.
- Barr, A. J., J. H. Goodnight, J. P. Salt and J. T. Helwig. 1976. A user's guide to SAS76. SAS Institute Inc., Post Office Box 10066, Raleigh, North Carolina 27605.

Table A. METHODS FOR DETERMINING MOISTURE CONTENT (M.C.) OF WHOLE SEEDS AND CHEMICAL COMPOSITION OF GRAINS, LEGUMES AND OILSEEDS USED

Crop	M.C. Determination		Chemical Composition (% d.b.)					NFE ^d
	°C	Hrs	Protein	Ash	Fat	Fiber		
Barley	130	20 ^a	14.9	2.6	1.9	5.0	75.6	
Chickpea (garbanzo)	103	72 ^b	27.0	3.1	3.3	11.8	54.8	
Cottonseed	103	72	22.7	4.6	23.6	16.6	32.5	
Dent corn (maize)	103	72 ^{a,b}	11.1	1.6	5.2	3.3	78.9	
Flaxseed	103	4 ^a	28.5	3.8	33.7	9.2	24.8	
Flint corn (maize)	103	72 ^{a,b}	12.2	1.4	4.5	3.3	78.5	
Lentil	103	72 ^b	27.7	2.8	0.4	4.4	64.6	
Mung bean (green gram)	103	72 ^b	27.4	3.7	0.8	5.0	63.1	
Mustard seed	130	4 ^a	21.8	5.5	39.2	8.3	25.1	
Oats	130	22 ^a	14.6	3.3	4.2	11.3	66.5	
Peanut (groundnut)	103	72 ^c	32.0	2.3	49.2	2.6	13.8	
Pigeonpea (tuar)	130	72 ^b	22.6	4.1	1.5	7.8	64.0	
Proso millet	130	4	12.5	3.0	4.2	7.9	72.4	
Rapeseed	130	4 ^a	17.3	3.9	46.3	8.6	23.9	
Rough rice, long grain	130	22 ^c	7.4	5.8	2.5	10.8	73.5	
Rough rice, medium grain	130	22 ^c	7.5	5.0	2.1	9.7	75.7	
Rye	130	16 ^a	13.3	1.9	1.7	2.8	80.3	
Sesame seed (til)	103	72	23.6	5.4	51.7	6.6	12.7	
Sorghum	103	72	12.5	1.7	4.1	2.2	79.4	
Soybean	103	72 ^b	39.8	5.3	16.4	7.0	31.5	
Sunflower seed	130	3 ^b	17.1	2.8	33.7	28.5	17.9	

^aAmerican Society of Agricultural Engineers. 1980-81. Agricultural Engineers Yearbook, p. 352. Publ. by the Society, 2950 Niles Road, St. Joseph, Michigan 49085.

^bUSDA. 1971. Oven methods for determining moisture content of grain and related agricultural commodities. U.S. Dep. Agr. Consumer and Marketing Service, Grain Division, Hyattsville, Maryland 20782.

^cKososki, A. R. 1977. Two methods of comparing equilibrium moisture of grains. M.S. thesis, Kansas State University, Manhattan 66506.

^dNFE = nitrogen-free extract.

Table B. EQUILIBRIUM RELATIVE HUMIDITY CONSTANTS FOR CHUNG-PFOST EQUATION

$$\text{ERH} = \text{EXP} \left[\frac{-A}{R} (T + C) \right] * \text{EXP} (-B * M_D)$$

Crop	A	B	C	Standard Error
Barley	745.49	16.18	46.64	0.0467
Chickpea	956.09	15.08	104.61	0.0504
Cottonseed	904.80	18.35	88.77	0.0470
Dent corn	1787.30	18.80	114.57	0.0314
Flaxseed	1439.40	22.67	140.50	0.0516
Flint corn	1945.80	20.21	109.75	0.0253
Lentil	1358.39	14.26	139.00	0.0475
Mung bean	101419.00	40.82	1147.50	0.1070
Mustard seed	1039.60	25.43	76.77	0.0563
Oats	1275.89	18.54	65.84	0.0268
Peanut, shelled	779.60	30.59	72.42	0.0548
Pigeonpea	1755.50	14.63	180.50	0.0511
Proso millet	1717.19	21.60	59.60	0.0235
Rapeseed	1379.40	28.23	116.14	0.0633
Rough rice, long grain	1359.10	19.93	61.72	0.0199
Rough rice, medium grain	1997.80	21.34	71.64	0.0215
Rye	2555.30	17.37	150.50	0.0546
Sesame seed	1419.90	37.30	115.70	0.0494
Sorghum	1299.50	18.70	61.93	0.0255
Soybean	773.63	12.93	132.12	0.0587
Sunflower seed	1065.60	23.81	92.74	0.0340
Wheat, durum ^a	921.65	18.08	112.35	-
Wheat, hard ^a	529.43	17.61	51.00	-
Wheat, soft ^a	726.49	23.61	35.66	-

^aData from American Society of Agricultural Engineers. 1980-81. Agricultural Engineers Yearbook, p. 328. Publ. by the Society, 2950 Niles Road, St. Joseph, Michigan 49085.

Table C. REGRESSION ANALYSIS OF THE RELATIONSHIP OF SPECIFIC HEAT AND MOISTURE CONTENT

$$\text{Specific Heat}^a \text{ (Btu/lb}\cdot\text{°F)} = A + B * \text{Moisture Content (\% w.b.)}$$

Crop	A	B	R ²
Barley	0.2098	0.0083	0.755
Chickpea	0.2389	0.0080	0.804
Cottonseed	0.2483	0.0067	0.865
Dent corn	0.1856	0.0012	0.777
Mung bean	0.2467	0.0059	0.964
Mustard seed	0.3078	0.0069	0.831
Oats	0.0338	0.0300	0.980
Peanut, shelled	0.2622	0.0107	0.983
Pigeonpea	0.2746	0.0058	0.774
Proso millet	0.2213	0.0073	0.776
Rapeseed	0.2973	0.0079	0.873
Rough rice, medium grain	0.2714	0.0042	0.817
Rye	0.2468	0.0097	0.938
Sorghum	0.2360	0.0063	0.967
Soybean	0.2678	0.0061	0.940
Sunflower seed	0.2819	0.0076	0.990
Wheat, hard ^b	0.2830	0.0072	-
Wheat, soft ^c	0.3340	0.0098	-

^aMultiply by 4.1868 to obtain kJ/kg·K (kJ = kilojoule, kg = kilogram, K = degrees Kelvin).

^bData from Pfalzner, P. M. 1951. The specific heat of wheat. Can. J. Tech. 29:261.

^cData from Kazarian, E. A. and C. W. Hall. 1965. Thermal properties of grain. Trans. Amer. Soc. Agr. Eng. 8:33.

Table D. REGRESSION ANALYSIS OF THE RELATIONSHIP OF TEST WEIGHT AND MOISTURE CONTENT

$$\text{Test Weight}^a \text{ (lb/bu)} = A + B * \text{Moisture Content (\% w.b.)}$$

Crop	A	B	R ²
Barley	51.83	-0.354	0.956
Chickpea	62.90	-0.372	0.820
Cottonseed	52.13	-0.616	0.964
Dent corn	63.84	-0.509	0.988
Flint corn	64.56	-0.512	0.963
Great northern bean	63.60	-0.552	0.978
Kidney bean	61.84	-0.419	0.914
Lentil	65.09	-0.660	0.936
Lima bean	57.99	-0.244	0.941
Mung bean	72.94	-0.862	0.954
Mustard seed	54.50	-0.246	0.990
Oats	43.45	-0.375	0.946
Peanut, shelled	50.09	-0.160	0.807
Pigeonpea	66.26	-0.316	0.903
Pinto bean	63.28	-0.477	0.953
Proso millet	57.19	-0.236	0.984
Rapeseed	53.17	-0.242	0.960
Rough rice, medium grain	44.26	+0.322	0.988
Rye	64.64	-0.789	0.948
Sorghum	63.34	-0.322	0.947
Soybean	57.97	-0.292	0.978
Sunflower seed	27.48	-0.188	0.916
Wheat, hard ^b	112.63	-0.204	-

^aMultiply by 12.8148 to obtain kg/m³.

^bData from Chung, D. S. and H. H. Converse. 1971. Effect of moisture content on some physical properties of grains. Trans. Amer. Soc. Agr. Eng. 10:612.

Table E. COMPUTER PROGRAM USED FOR GENERATION OF TABLES

```

00C1      INTEGER GR(3)
00C2      DIMENSION ERH(5),KT(5)
00O3      9 FORMAT(' ',2X,3A4,1X,12,1X,F9.2,1X,F5.2,1X,F7.2,2(1X,F6.4),
           12X,F6.2,2X,F6.4)
00C4      10 FORMAT('C',32X,3A4,/)
00O5      11 FCRMAT(3A4,1X,12,1X,F9.0,1X,F5.0,1X,F7.0,4(1X,F6.0))
00C6      12 FCRMAT('1')
00C7      8 REAC(5,11,END=100) GR,M,A,B,C,SA,SB,TA,TB
00O8      WRITE(6,12)
00O9      WRITE(6,9) GR,M,A,B,C,SA,SB,TA,TB
0010      WRITE(6,10) GR
0011      13 FCRMAT(' ',70(' '))
0012      14 FCRMAT(' ',1X,'MOISTURE',17X,'E.R.H.',21X,'SP.HEAT',2X,'DENSITY')
0013      18 FCRMAT(' ',2X,'(ZW.8)',19X,'(1)',21X,'(KJ/KG-K)',3X,'(KG/M)')
0014      16 FORMAT(' ',11X,'10 C',4X,'20 C',4X,'25 C',4X,'30 C',4X,'40 C',
           17X,'25 C',5X,'25 C')
0015      19 FCRMAT(' ',11X,'50 F',4X,'68 F',4X,'77 F',4X,'86 F',4X,'104 F',
           16X,'77 F',5X,'77 F')
0016      24 FCRMAT('0',3X,12,2X,5(4X,F4.1),6X,F5.2,4X,F6.1)
0017      WRITE(6,13)
0018      WRITE(6,14)
0019      WRITE(6,18)
0020      WRITE(6,13)
0021      WRITE(6,16)
0022      WRITE(6,19)
0023      WRITE(6,13)
0024      KT(1)=10
0025      KT(2)=20
0026      KT(3)=25
0027      KT(4)=30
0028      KT(5)=40
0029      DO 50 N=1,23
0030      M=M+1
0031      WM=(M/(100.-M))
0032      DC 51 K=1,5
0033      ERH(K)=EXP(-A/(1.987 *(KT(K)+C))*EXP(-B*WM))*100
0034      51 CCNTINUE
0035      HEAT=4.1868*(SA+SB*M)
0036      DEN=12.8148*(TA-TB*M)
0037      WRITE(6,24) M,(ERH(I),I=1,5),HEAT,DEN
0038      50 CCNTINUE
0039      WRITE(6,13)
0040      GO TO 8
0041      100 CCNTINUE
0042      WRITE(6,12)
0043      STOP
0044      END

```

Data cards follow according to format 11.