Moisture Contraction of Spanish Peanuts[1]

Marvin R. Paulsen[2] and Gerald H. Brusewitz[3]

ABSTRACT

The linear coefficient of moisture contraction for skinned Spanish peanut kernels was determined at 40°C and at 20, 42, 70, and 80% drying air relative humidities. Kernel lengths and diameters were measured optically with a microprojector. Cubical coefficients of moisture contraction were calculated from the linear-coefficients by approximating peanut volume by a prolate spheroid shape. Cubical coefficients ranged from 5.5 to 7.71 x 10^{-3} cm^3/cm^3 % MC and generally increased as drying air relative humidities increased.

Peanuts are an important source of protein and oil for use in human food. In the processing of peanut butter and other peanut products for food, it is generally desirable to eliminate a source of bitter taste by removing the skin (testa) from the peanut kernel through a process known as blanching. Effective blanching processes were found to be dependent on the amount of moisture removed from the peanut during forced air heating (Shackelford, 1972; Woodruff, 1973). Since moisture removal is generally accompanied with a reduction in volume of a material, it was believed that the cubical coefficient of moisture contraction for peanut kernels may be an important physical property in peanut blanching. Due to the physical nature of peanut skins, no attempt was made to measure any skin properties and only skinned kernels were investigated in this study.

The objective of this study was to experimentally determine the linear and cubical coefficients of moisture contraction for skinned Spanish peanut kernels at 40°C as a function of drying air relative humidity.

The cubical coefficient of moisture contraction for brown rice was determined by Prasad, et al. (1975) and Mannapperuma (1975) by multiplying by three the average measured linear coefficient for length, width, and thickness dimensions. The linear coefficients were found by optically measuring rice dimensions at moisture contents ranging from 5.5 to 23.5% dry basis. The cubical coefficient for brown rice was found to be 1.215 x 10^{-2} cm^3/cm^3%.

Steele and Brown (1974) determined the change in dimensions of freshly dug Virginia and Florigiant peanuts which were dried in a controlled chamber at 30°C and 75% relative humidity. The kernels were optically profiled for length and diameters perpendicular and parallel to the cotyledon interface after exposure periods of 0, 1, 2, 4, 8, and 16 days. Based on an average of eight kernels for each exposure period the kernel dimensions were found to decrease linearly with a decease in dry base moisture content.

Van Arsdel, et al. (1973) found that the rate of drying affected the final volume of potato cubes. Dehydrated 0.95 cm potato cubes which were dried at 65°C and 7% relative humidity for 3¾ hours to 11% dry base moisture had a bulk density approximately one-half that of an equal weight of potato cubes which were dried to the same moisture content with nearly saturated air for 15 hours. Thus, a decrease in drying rate decreased the volume of potato cubes.

Woodward and Hutchinson (1972) reported that splitting of peanut kernels increases as drying rate increases. Virginia, Runner, and Spanish whole green peanut kernels with their skins removed were dried at 24°C and relative humidities of 12, 40, 60, and 80% to approximately 12% moisture content. After drying, the opposing displacement between cotyledons at the end opposite the germ was measured. For Virginia and Runner peanuts the average displacement was approximately 0.14, 0.11, and 0.04 cm at relative humidities of 12 to 40, 60, and 80%, respectively. For Spanish peanuts the average displacement was approximately 0.06, 0.03, and 0.02 cm at relative humidities of 12 to 40, 60, and 80%, respectively. Thus, rapid drying at low relative humidities caused the peanut kernels to spread apart at the end opposite the germ.

Materials and Methods

The coefficients of moisture contraction due to drying were determined for naturally moist freshly-dug Spanish peanuts. Kernel moistures varied from 28 to 58%* with an average moisture content of 43%. Due to the high moisture contents and short storage life, the peanuts were stored at 4°C and were replaced with freshly dug peanuts approximately every two weeks. The effect of peanut digging dates on the coefficient of moisture contraction was not investigated. The pods were hand-shelled and the skins were carefully removed from whole kernels immediately prior to testing. Apical and basal kernels were tested separately to determine if a difference in the coefficient of moisture contraction existed for those kernels.

Peanut kernels were dried in a clear plexiglas environmental chamber which was 7 x 12 x 40 cm as shown in Figure 1. Drying air was maintained at a constant temperature and relative humidity by an Aminco-Aire precision regulated temperature-humidity air supply unit and circulated through a 0.4 m^3 insulated chamber. Air at 40°C and 20, 42, 70, or 80% relative humidity was passed through the environmental chamber at approximately 15 m/min. As only six kernels (3 apical and 3 basal) were dried in the environmental chamber at one time, it was assumed that a negligible increase in drying rate would occur by passing air velocities greater than 15 m/min over the kernels.

A Wilder microprojector equipped with a 20X magnification lens was utilized to optically measure the lengths

[1]Journal Article No. 3048 of the Oklahoma Agricultural Experiment Station.

[2]Research Associate, Agricultural Engineering Department, University of Illinois, Urbana, Il. 61801.

[3]Associate Professor, Agricultural Engineering Department, Oklahoma State University, Stillwater, Ok. 74074.

*All moisture contents reported are expressed in percent dry basis unless otherwise indicated.

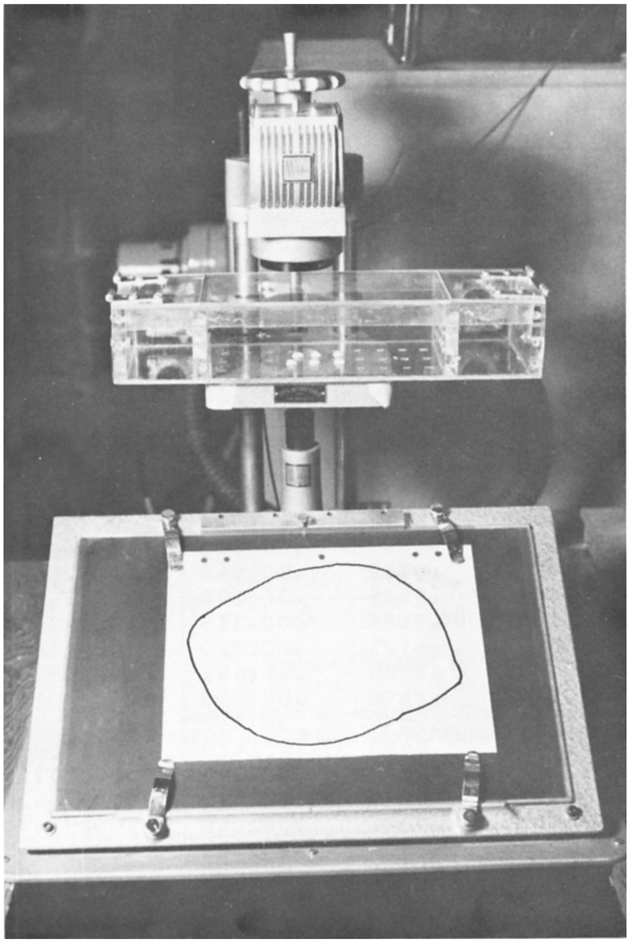

Fig. 1. Wilder Microprojector Equipped with 20X Lens and Environmental Chamber for Drying Peanuts.

and diameters of kernels placed in the environmental chamber (See Figure 1). The magnified image of an individual kernel was projected onto a grid from which the entire outline was traced. Then length and diameter dimensions were recorded from the trace to the nearest 0.025 mm.

Kernels dried at 20, 42 and 70% relative humidity were optically measured initially and then 0.5, 1, 2, 4, and 24 hours from the start of drying. Kernels dried at 80% relative humidity were measured initially and at 1, 2.5, 4, and 24 hours from the start of drying. After each measurement, the kernels were individually removed from the environmental chamber and weighed on an analytical balance to the nearest 0.0001 g. The kernels were out of the chamber for approximately two minutes for each weighing and it was assumed that this periodic removal did not significantly affect the drying rate. After the 24-hour measurements, the kernels were oven-dried for 24 hours at 105°C so that moisture contents could be calculated from the weighings. The kernels were weighed and optically measured again after oven drying.

The whole kernels were orientated so the cotyledon interface was in a vertical plane. This enabled length and a diameter dimension perpendicular to the cotyledon interface to be measured. Preliminary testing revealed that as a kernel dried, the bottom kernel surface would distort slightly causing the kernel to change its orientation between times it was viewed on the microprojector. Consequently, a thin slice approximately one mm thick was removed from the bottom surface of the whole kernels so that a nearly flat surface was obtained. It was assumed that removal of the thin slice did not significantly alter the shrinkage characteristics of the kernel.

In measuring the whole kernel diameters, some cotyledons would occasionally spread slightly apart after some initial drying and volume shrinkage occurred. Because of the temporary handling required for weighing it was not possible to make measurements of cotyledon displacement at the identically same position. Kernels were visually checked to see that cotyledons were always intact before kernel dimensions were recorded. Readings were taken such that dimensional changes could be assumed due only to moisture contraction. It was assumed that the drying and shrinkage characteristics of the kernel were not significantly different from a kernel fully intact.

A least squares regression was performed for each kernel to determine the slopes, $\Delta L/\Delta M$ and $\Delta D/\Delta M$, of the straight lines depicting kernel length and diameter versus moisture content, respectively. The size of a kernel was believed to affect the moisture contraction of the kernel; therefore, $\Delta L/\Delta M$ and $\Delta D/\Delta M$ were divided by their respective oven dry lengths or diameters. The relative change in length and diameter dimensions were denoted by $\Delta L/L\ \Delta M$ and $\Delta D/D\ \Delta M$ (cm/cm %). The terms $\Delta L/L\ \Delta M$ and $\Delta D/D\ \Delta M$ are linear moisture contraction coefficients and were denoted as α_L and α_D, respectively.

An analysis of variance was performed for α_L and α_D. Four levels of humidity, 20, 42, 70 and 80% were investigated as main effects. For each humidity level, two replications were performed independently. Within each replication three kernels of each type, apical and basal, were measured at each humidity level. A total of 48 whole kernels were measured and analyzed.

The cubical coefficient of moisture contraction was computed from the linear coefficient by calculating the change in volume per unit volume which would occur for a one percent loss in moisture. The method of calculating the cubical coefficient of moisture contraction was to approximate the volume of a peanut kernel at various moisture contents with a prolate spheroid. The volume, V, of a prolate spheroid, an elipse rotated about its major axis, can be written:

$$V = (4\pi/3)\ (L/2)\ (D/2)^2 \qquad [1]$$

where L/2 and D/2 are the half-lengths of the major and minor axes, respectively. The terms L and D are the oven-dry dimensions of the peanut kernels. The volume, V_m, of the kernel at some moisture content, M, was calculated by:

$$V_m = (4\pi/3)(L/2 + \alpha_L\ M\ L/2) \times (D/2 + \alpha_D\ M\ D/2)^2 \qquad [2]$$

The cubical coefficient of moisture contraction, a_m, for a ΔM change in moisture content was defined as:

$$a_m = (V_m - V_{m-1}) / (V_m\ \Delta M) \qquad [3]$$

where: V_m = the volume calculated at the moisture M

V_{m-1} = the volume calculated at the moisture M - ΔM

ΔM = the difference in % moisture content at V_m and V_{m-1}

A Fortran computer program was used to calculate a_m from 1 to 90 percent moisture content by increments, ΔM, of one percent for two drying rates. The length, L, of 1.033 cm was obtained by averaging the oven-dry diameters over all relative humidities.

Results

Spanish peanut length and diameter dimensions were found to decrease linearly with moisture loss. The slopes for length ($\Delta L/\Delta M$) and diameter ($\Delta D/\Delta M$) are shown in Table 1.

The analysis of variance performed on α_L and

Table 1. Moisture contraction data for Spanish peanuts

TYPE*	HUM	IMOIST	LENGTH	ΔL/ΔM	α_L	DIAM	ΔD/ΔM	α_D
A	20	39.46	1.1525	.002255	.00195662	.8875	.001855	.00209014
A	20	36.47	1.1500	.002185	.00190000	.8325	.001265	.00151952
A	20	35.56	1.1275	.002320	.00205765	.7675	.001655	.00215635
A	20	34.63	0.9925	.002395	.00241310	.8175	.001990	.00243425
A	20	46.58	1.1450	.002170	.00189520	.8200	.000925	.00112805
A	20	38.13	1.0150	.002285	.00225123	.8250	.001430	.00173333
B	20	35.71	0.9925	.002655	.00267506	.8050	.001610	.00200000
B	20	40.32	1.0775	.001155	.00107193	.7400	.003040	.00410811
B	20	37.14	0.9575	.002465	.00257441	.7900	.001945	.00246203
B	20	35.82	1.0400	.001655	.00159135	.7700	.001580	.00205195
B	20	37.95	0.9050	.001740	.00192265	.8300	.001275	.00153614
B	20	39.96	1.0150	.001950	.00192118	.8475	.001520	.00179351
A	42	28.41	1.1725	.002500	.00213220	.8075	.002045	.00253251
A	42	42.69	1.1275	.001800	.00159645	.7825	.001295	.00165495
A	42	38.74	1.2375	.002090	.00168889	.8225	.001205	.00146505
A	42	51.85	1.2200	.002045	.00167623	.7975	.001865	.00233856
A	42	48.22	0.9800	.002370	.00241837	.8150	.001910	.00234356
A	42	51.93	1.1750	.002740	.00233191	.7500	.001965	.00262000
B	42	37.28	1.0275	.002325	.00226277	.8750	.001540	.00176000
B	42	35.86	1.0700	.001890	.00176636	.8525	.001670	.00195894
B	42	43.59	0.8575	.002220	.00258892	.8625	.001315	.00152464
B	42	51.67	0.9650	.002205	.00228497	.8125	.001720	.00211692
B	42	49.29	0.9400	.002390	.00254255	.9000	.001695	.00188333
B	42	46.53	1.0450	.002115	.00202392	.8600	.001205	.00140116
A	70	32.63	1.1750	.003995	.00340000	.9050	.001460	.00161326
A	70	35.27	1.0500	.002205	.00210000	.8450	.001470	.00173964
A	70	35.08	1.1350	.004250	.00374449	.8275	.002075	.00250755
A	70	50.97	0.8750	.002850	.00325714	.8275	.002620	.00316616
A	70	57.85	1.1075	.002655	.00239729	.7400	.002040	.00275676
A	70	45.17	1.1825	.002840	.00240169	.8325	.002105	.00252853
B	70	38.67	1.0250	.003710	.00361951	.8725	.001800	.00206304
B	70	37.15	1.0525	.003255	.00309264	.8950	.003255	.00363687
B	70	34.41	0.8725	.003770	.00432092	.8875	.001980	.00223099
B	70	55.79	1.0075	.002055	.00203970	.8875	.002105	.00237183
B	70	48.90	1.0375	.002840	.00273735	.8875	.002045	.00230423
B	70	55.43	0.9425	.003465	.00367639	.8800	.001820	.00206818
A	80	44.33	0.9925	.002915	.00293703	.7475	.002065	.00276254
A	80	40.01	0.9800	.003750	.00382653	.8650	.002240	.00258960
A	80	42.99	1.1825	.003130	.00264693	.8025	.002080	.00259190
A	80	50.75	1.1450	.003765	.00328821	.7975	.002430	.00304702
A	80	47.01	1.0525	.003785	.00359620	.7850	.002385	.00303822
A	80	54.39	1.1450	.004090	.00357205	.9175	.002690	.00293188
B	80	39.51	0.7750	.002180	.00281290	.6875	.002035	.00296000
B	80	45.33	0.8250	.003250	.00393939	.8850	.001850	.00209040
B	80	46.15	0.9700	.003090	.00318557	.8175	.002265	.00277064
B	80	52.18	0.9150	.003165	.00345902	.7850	.001780	.00226752
B	80	44.62	0.8850	.002735	.00309040	.7900	.002220	.00281013
B	80	46.86	0.9275	.003270	.00352561	.8425	.002380	.00282493

* A = Apical Peanut Kernel   B = Basal Peanut Kernel

α_D, indicated that no significant difference (95% probability level) was found between apical or basal kernel types for α_L and α_D. Relative humidity did not significantly affect α_D but did significantly affect α_L. An LSD of 0.00882 was needed for a significant difference (95% probability level) to exist between relative humidities. No significant differences between 20 and 42% and between 70 and 80% relative humidities were found for α_L. The α_L values were thus averaged together to give one value (0.00206 cm/cm %) for the 20 to 42% range and another value (0.00319 cm/cm %) for the 70 to 80% range. A significant difference was however found between the 20-42 and 70-80% relative humidities. The value of α_D (0.00230) cm/cm %) was obtained by averaging over all relative humidities for the kernels.

The length and diameter dimensions of peanut kernels decreased linearly with moisture loss. Therefore, the computer program was used for computing a_m from eq. 3 using the length and diameter measured values. Figure 2 shows the computer values of a_m as a function of moisture content for two different drying air relative humidity ranges. Values of a_m decreased linearly as moisture increased. Further explanation and data for calculating the cubical coefficients of moisture contraction can be obtained from Paulsen (1975).

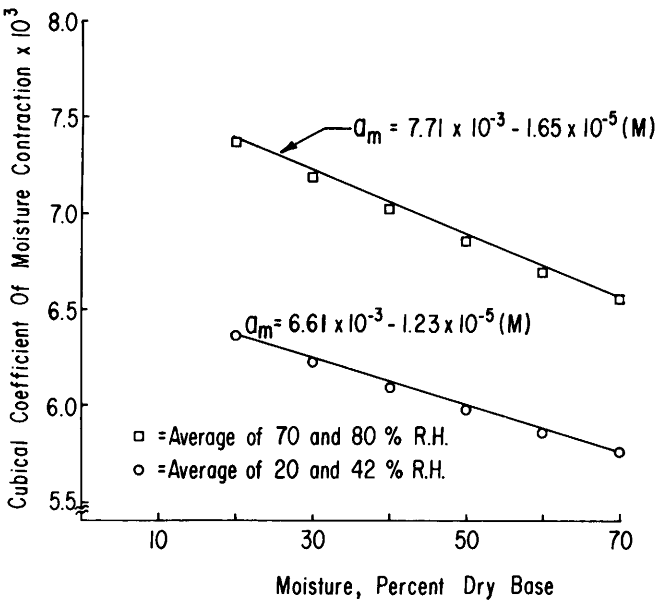

Fig. 2. Cubical Coefficients of Moisture Contraction and Regression Lines as a Function of Moisture Content and Drying Air Relative Humidity.

The relative humidity range used for drying peanuts with 40°C air for 24 hours produced average moisture contents of 4.8 and 10.5% for the relative humidity ranges of 20 to 42% and 70 to 80%, respectively. It is theorized that drying rate affected the final volume. Van Arsdel, et al. (1973) stated that if a highly shrinking material was dried quickly and the outer surface became much drier than the center, the outer surface was subjected to sufficient tension to permanently set the surface in nearly its original dimensions. When the center finally dried and contracted, the internal stresses pulled the material apart and the dried material contained many cracks and holes. Conversely, if the material was dried slowly with a small moisture gradient from outer surface to the center core, internal stresses were minimized and the material contracted fully to a solid core. Peanut kernels dried slowly at 70 to 80% relative humidities were found to have larger moisture contraction coefficients than those kernels dried more rapidly at 20 to 42% relative humidities. See Figure 2.

Discussion

The cubical coefficients of moisture contraction coupled with thermal expansion coefficients have been used to predict volume changes in individual Spanish peanuts during drying. The cubical coefficient of thermal expansion for Spanish peanut kernels was found by Paulsen (1975) to be:

$$a_m = 5.219 \times 10^{-4} + 2.97 \times 10^{-5} (\text{Ln } M) \qquad [4]$$

Equation 4 was determined for 0.5 to 15.7% moisture content Spanish peanut kernels heated from 25 to 90°C. The moisture contraction (Eq. from Fig. 2) and thermal expansion (Eq. 4) coefficients were used by Paulsen (1975) to predict the final volume of a skinned peanut kernel after heating, drying, and cooling. When these coefficients were applied to the heating and drying conditions used by Shackelford (1974) there was shown to be a correlation between percentage of peanuts blanched and the predicted final kernel volume.

Summary and Conclusions

The cubical coefficients of moisture contraction for skinned Spanish peanut kernels varied from 5.5 x 10^{-3} to 7.71 x 10^{-3} cm^3/cm^3 % depending on moisture content and drying rate. In general as moisture contents increased, a_m decreased. Peanut kernels dried slowly at high relative humidities were found to have larger cubical coefficients of moisture contraction than kernels dried more rapidly at lower relative humidities.

Literature Cited

Mannapperuma, J. D. 1975. Analysis of thermal and moisture stresses caused during drying of brown rice. Unpublished M.S. thesis, Louisiana State University.

Paulsen, M. R. 1975. Thermal expansion and moisture contraction as related to blanching of Spanish peanuts. Unpublished Ph.D. thesis, Oklahoma State University, Stillwater, OK.

Paulsen, M. R. and G. H. Brusewitz. 1975. Coefficient of cubical thermal expansion for Spanish peanut kernels and skins. ASAE Paper No. 75-3010 presented at the Summer Meeting, American Society of Agricultural Engineers, St. Joseph, MI.

Prasad, S., J. D. Mannapperuma, and F. T. Wratten. 1975. Thermal and hygroscopic expansion of brown rice. ASAE Paper presented at Southwest Regional April Meeting at Fountainhead State Park, Oklahoma, American Society of Agricultural Engineers, St. Joseph, MI.

Shackelford, P. S. 1974. Skin removal from Spanish peanuts by heating to moderate temperatures. Unpublished Ph.D. thesis, Oklahoma State University, Stillwater, OK.

Steel, J. L., and L. W. Brown. 1974. Dimensional changes of Virginia-type peanut pods and seeds during drying. American Peanut Research and Education Association Journal. Volume 6, pp. 30-40.

Van Arsdel, W. B., M. J. Copley, and A. J. Morgan. 1973. Food Dehydration Volume I Drying Methods and Phenomena, 2nd ed. AVI Publishing Co., Inc., Westport, CT.

Woodruff, J. G. 1973. Peanuts-production, processing, products. The AVI Publishing Co., Inc. Westport, CT.

Woodward, J. D. and R. S. Hutchinson. 1972. The effect of drying rates on separation of cotyledons of bald kernels. American Peanut Research and Education Association Journal, Volume 4, pp. 89-95.