Seed Size and Storage Effects on Carbohydrates of Peanuts

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Carbohydrate changes during cold storage (4 °C; 65% relative humidity) were determined in peanut kernels of selected sizes. Quantitative measurements were made on fructose, glucose, inositol, raffinose, ribose, sucrose, and stachyose contents. Seed size had a significant effect on all individual carbohydrate contents on a per seed basis. Storage time significantly affected the levels of all of the above components except raffinose and ribose. Information is given on the relationship between physiological maturity and seed size of Florigiant peanuts. Some of the changes in carbohydrate contents are discussed with reference to this relationship.

Changes in the carbohydrate levels of various fruits and vegetables during storage are well documented, e.g., mushrooms (Hammond and Nichols, 1975), rhubarb (Rutherford and Ali, 1977), carrots (Hansen and Rumpf, 1974), sweet potatoes (Reddy and Sistrunk, 1980), tomatoes (Beuscher, 1975), and potatoes (Arreguin-Lozano and Bonner, 1949; Muller-Thurgau, 1882). Although the carbohydrates of peanuts have been identified, quantitated (Tharanathan et al., 1975, 1976; Holley and Hammons, 1968; Newell et al., 1967), and shown to be the precursors of compounds imparting the flavor characteristics of roasted peanuts (Newell et al., 1967; Mason et al., 1969), little, if anything, has been reported as to whether or not the levels of those carbohydrates change during storage of peanuts. All shelled peanuts used for commercial processing are placed in cold storage for a period varying from 24 h to over 1 year (average of 3–4 months). Changes in the composition and quantity of carbohydrates could affect their quality when roasted.

The market grades of peanuts and, thus, their market value (Hinds and Kromer, 1973) are based upon screen size, i.e., whether the kernel rides or falls through screens of certain sizes. The screen-size dermarcations between market grades have been based more on economic considerations than on quality. It has been indicated that many current grades and standards do not accurately describe the characteristics of the ultimate product (Hinds and Kromer, 1973). Thus, a need exists to understand the relationships between peanut size and chemical composition. The size distribution of Florigiant, Florunner, and Starr peanuts has been investigated (Davidson et al., 1978), and the composition of peanuts at various physiological maturity (PM) levels has been determined (Pattee et al., 1974). However, there is a paucity of information relating peanut size with either composition or PM.

This study was undertaken to provide information on the effect of storage duration on the quantities of various carbohydrates in peanuts of certain selected screen sizes and to determine the relationship of peanut size to PM stage and number of kernels per kilogram.

MATERIALS AND METHODS

Florigiant peanuts grown on North Carolina farms in 1978 were obtained from a commercial sheller pregraded into U.S. No. 1, Medium, and Extra Large Virginias. We sized the peanuts by width to obtain the designed screen sizes of 5.95, 7.14, 7.94, and 8.73 mm ($^{15}/_{64}$, $^{18}/_{64}$, $^{20}/_{64}$, and $^{22}/_{64}$ in.). The peanuts were first passed through a peanut presizer with the separation between rollers set at the desired screen size plus 0.4 mm to establish an upper size limit for that size category of seeds. The riding fraction was passed through the presizer twice more for maximum recovery of the desired seed size. All fall-through kernels were then passed over the presizer with the rollers set at the desired screen size. The riding fraction was saved, and the desired fraction obtained from the presizer was then screened. The official grade shaker was used with the desired slotted screen on the bottom and the next larger screen (plus 0.4 mm) on top. The shaker was operated for 20 s on each shaking cycle.

Moisture content of the peanuts was 8% at purchase and 6.3% just before screening. No moisture content changes occurred during screening and storage; thus, potential seed size changes resulting from moisture reduction (Slay, 1976) were not a consideration.

Storage rooms were maintained at 4 °C and 65% relative humidity. At preset times, three replicated samples, 50 g each, were withdrawn and analyzed for carbohydrates as described by Oupadissakoon et al. (1980).

Florigiant peanuts used in tests to determine the PM–screen size relationship were grown at Lewiston, NC, during 1974 according to recommended cultural practices (Perry, 1974). Samples consisting of two plants from each of four replications were hand dug on Sept 18 and 25 and Oct 2, 9, and 16, 1974. The plants with fruit attached were stored overnight at 4 °C. The next day all fruits were stripped from the plants, opened, and classified as to PM as described by Pattee et al. (1974). The kernels were air-dried to a constant weight at room temperature. The moisture content was ~5%. The screen-size distribution was determined for each harvest date with official Virginia-type grading screens and the grade shaker. The shaking time was 20 s.

Data analysis of variance was performed as described by the General Linear Models procedure (Barr et al., 1979).

RESULTS AND DISCUSSION

Data from the 1974 Florigiant crop grown in Lewiston, NC (Table I), indicated that 59.3% of the peanuts at stage 7 (defined as inner pericarp, beginning to appear cottony; kernel, torpedo to round shaped; embryonic axis end of kernel, pink; other end, white to light pink) were large enough to be retained for marketing. By stage 9 this value was up to 99%, and 74.1% were large enough to meet Medium grade standards (rides a 7.14 × 25.4 mm slot screen) or above. Only a small percentage of the peanuts of stage 10 and above were small enough to be considered U.S. No. 1 Virginia grade. Apparently for Virginia-type grade standards, the U.S. No. 1 grade (rides a 5.95 mm and falls a 7.14 × 25.4 mm slot screen) includes mostly peanuts

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Table I. Relationship of Seed Size to Physiological Maturity (PM) of Florigiant Peanuts[a]

PM	% at seed size, mm width, of <5.95	5.95	6.35	6.75	7.14	7.54	7.94	8.73	9.52	10.32
7	40.7	15.5	18.9	16.5	6.1	2.3				
8	5.9	6.7	19.5	24.2	21.8	12.2	7.9	2.0		
9	1.0	1.7	7.1	16.2	19.5	17.4	23.1	13.8	0.3	
10				4.0	14.3	20.3	27.0	31.5	3.0	
11			0.5	0.5	3.8	8.3	24.8	52.1	9.5	0.5
12		0.5	0.5	0.5	2.4	5.7	19.9	57.8	10.0	2.8

[a] Data were based on samples taken on Sept 18 and 25 and Oct 2, 9, and 16, 1974. Samples were dried to ~5% moisture content before screening.

Table II. Influence of Seed Size and Storage Time on the Carbohydrates of Peanut

storage time, months	carbohydrates, ng/g — width of whole seed size, mm (in.) 5.95 (15/64)	7.14 (18/64)	7.94 (20/64)	8.73 (22/64)	split seed	width of whole seed size, mm (in.) 5.95 (15/64)	7.14 (18/64)	7.94 (20/64)	8.73 (22/64)	split seed
	Fructose					Glucose				
0	290 ± 42[a]	220	202	248	266	108 ± 90[a]	119	95	140	88
3	225 ± 35[b]	123	170	159	207	141 ± 74[b]	195	85	120	85
5	242 ± 35	242	198	208	209	160 ± 74	108	80	71	62
6	260 ± 35	250	173	297	248	86 ± 74	95	74	136	111
7	632 ± 42	330	306	272	280	234 ± 90	126	122	91	102
8	580 ± 42	370	320	318	296	297 ± 90	176	129	108	101
9	414 ± 35	290	242	253	217	160 ± 74	116	100	87	50
	Stachyose					Ribose				
0	1880 ± 780[a]	4500	5230	6160	4490	49 ± 15[a]	40	18	14	34
3	3780 ± 637[b]	3620	3990	5160	3879	39 ± 12[b]	41	348	63	469
5	3970 ± 637	5670	6110	5420	5200	21 ± 12	8	23	29	31
6	4100 ± 637	5340	4070	5010	5207	40 ± 12	41	39	278	196
7	3700 ± 780	3870	4540	3830	3620	5 ± 15	77	35	287	41
8	3350 ± 780	4370	3790	4070	3630	– ± 15	51	22	35	498
9	3260 ± 637	4170	4520	4420	3230	10 ± 12	38	21	339	39
	Sucrose					Inositol				
0	28590 ± 2536[a]	29700	31520	31520	35000	203 ± 50[a]	214	180	146	150
3	38000 ± 2071[b]	29020	27820	27520	30820	204 ± 41[b]	172	159	114	110
5	34640 ± 2071	35040	28050	27430	31340	221 ± 41	230	230	125	135
6	29800 ± 2071	28380	25680	27000	29380	243 ± 41	225	283	306	155
7	45930 ± 2536	33140	28360	27010	30050	346 ± 50	195	254	114	117
8	48300 ± 2536	33630	29300	27220	31190	365 ± 50	236	152	150	135
9	40400 ± 2071	33470	29640	30080	30130	290 ± 41	214	336	202	113
	Raffinose					Total				
0	310 ± 78[a]	538	507	733	503	31420 ± 3041[a]	35320	37750	35770	40510
3	480 ± 64[b]	470	442	607	400	42860 ± 2483[b]	33640	32700	33770	35600
5	525 ± 64	600	538	540	529	39770 ± 2483	41830	35220	33820	37500
6	370 ± 64	507	447	528	411	34890 ± 2483	34860	30770	33300	36050
7	453 ± 78	510	525	436	394	51300 ± 3041	38250	34140	31770	34620
8	570 ± 78	392	424	471	448	53460 ± 3041	39210	34130	32370	35850
9	460 ± 64	507	536	505	392	44990 ± 2483	38830	35160	35580	34170

[a] ±Standard deviation of the mean for two observations—applies across all seed sizes. [b] ±Standard deviation of the mean for three observations—applies across all seed sizes.

of PM 7–9, the Medium grade (rides a 7.14 mm and falls a 7.94 × 25.4 mm slot screen), PM 9–10, the Extra Large grade (rides a 7.94 × 25.4 mm slot scrren), PM 10 and above. Full maturity is considered to be stage 12 (Pattee et al., 1974). Such differences in maturity could contribute significantly to the composition of peanuts and their response to handling conditions during the marketing process.

On the basis of the above data and general observations from our research on peanut maturity and quality, we selected four seed sizes plus splits to study their carbohydrate compositions and changes in those compositions as a result of storage. These seed sizes allowed us to obtain information on the minimum seed size in each of the three market grades of Virginia-type peanuts. Seed count is a second criterion which must be met in marketing peanut kernels, and it is general practice to combine peanuts of the next higher (0.4 mm) screen size into a grade to meet this marketing requirement. The 7.14- and 7.94-mm size seeds allowed us to look at the largest size seeds generally found in the U.S. No. 1 and Medium grades. The data in Table I suggest that 8.74-mm seeds were representative of the fully mature peanut kernel.

Qualitatively the kinds of carbohydrates isolated agreed with those found by Newell et al. (1967) and Tharanathan et al. (1975, 1976) (Table II). Quantitative comparisons between the values given by Oupadissakoon et al. (1980) for Florigiant and our values for 7.14–7.94-mm seeds at time zero demonstrated good agreement. Such agreement helps to establish the validity of our time zero values and their usefulness in comparisons, even though the standard deviations were high for some observations.

Seed size significantly affected the concentrations (nanograms per gram) of all carbohydrates except ribose. Although concentration was not linearly related with seed size, it was generally highest for the smallest seed size.

Table III. Relationship between Seed Size and Seed Count per Kilogram in Commercially Obtained 1978 Crop Peanuts

seed size, mm	seed count per kg[a]
5.95	2547
7.14	1663
7.94	1288
8.73	1028
splits	1268

[a] Average of five samples.

Raffinose, sucrose, and stachyose components were the exceptions. Also, storage time significantly affected the concentrations of all components except raffinose and ribose. It has been generally accepted that the carbohydrate content of peanuts does not change with storage time, and this concept was supported by our data for total carbohydrates, which did not change significantly. However, the fact that the individual components did change indicates that information on the quality effects of such changes should be obtained.

In potatoes, for example, reducing sugar content increases during storage at 5 °C for 3–6 months, and this increase adversely affects (darkens) the color of french fries and chips. Reconditioning the potatoes at room temperature may result in the metabolism of these sugars, with a commensurate improvement in the color of the products (Smith, 1967; Ryall and Lipton, 1972; Gould et al., 1979). Similarly, a better understanding of the sugar changes in peanuts during storage may enable us to develop the quality of processed peanuts to its highest potential.

The complexity of the changes during storage was illustrated by the significant interaction of seed size and storage time for fructose, glucose, and sucrose. The known relationships between fructose, glucose, and sucrose would suggest that an increase in fructose and glucose contents during storage as observed for the 5.95-mm-size seeds would be accompanied by a decrease in sucrose content. Such a relationship was not observed, and biochemical observations for peanuts that would help account for the concurrent rise and fall of the various components are not available. A discussion of the known enzymic pathways for carbohydrate metabolism on the basis of these initial observations does not seem appropriate.

We indicated earlier that seed count was a part of each Virginia-type market grade. The seed count for the split seeds was about the same as that for the 7.95-mm-size seeds. Split seeds generally arise because the intact seed is unable to pass the screens during shelling. The seed distribution data (Table I) partly explains how oversize seeds arrived at these screens, i.e., the natural distribution of seed size within the presized pod sizes.

We calculated the carbohydrate values on a per seed basis by multiplying the data in Table II by 1000 and dividing by the appropriate value in Table III. These per seed values enable one to observe the effect of maturity not only on carbohydrate content but also on changes in the carbohydrate content during storage. On a per seed basis, the effect of seed size on carbohydrate components was magnified, as indicated by fact that the differences observed were highly significant (0.01) for all components including ribose. Although maturity effects on total carbohydrates have been demonstrated (Amaya-Farfan et al., 1978; Basha et al., 1976), we are probably the first to have investigated maturity effects on individual carbohydrate components. Although the same components were significantly affected by storage time whether the data were analyzed on the basis of seed weight or individual seeds, the effects on glucose and sucrose contents as analyzed by the latter method were not as large. The interactions of seed size and storage time were not present in the per seed data, indicating that the trends in the data were nearly parallel. The trend for a linear increase in carbohydrates with seed size was in keeping with observations that immature peanuts develop a more atypical roasted flavor than mature peanuts (Newell et al., 1967). Future studies will aim at relating observed changes in seed composition to the roasted flavor quality of peanuts.

LITERATURE CITED

Amaya-Farfan, J.; Basha, S. M. M.; Young, C. T. *Cienc. Cult. (Sao Paulo)* **1978**, *30*, 79.

Arreguin-Lozano, B.; Bonner, J. *Plant Physiol.* **1949**, *24*, 720.

Barr, A. J.; Goodnight, J. H.; Sall, J. P.; Blair, W. H.; Chilko, D. M. "SAS User's Guide"; SAS Institute Inc.: Cary, NC 27511, 1979; pp 237–263.

Basha, S. M. M.; Cherry, J. P.; Young, C. T. *Cereal Chem.* **1976**, *53*, 586.

Beuscher, R. W. *HortSci.* **1975**, *10*, 158.

Davidson, J. I., Jr.; Blankenship, P. D.; Chew, V. *Peanut Sci.* **1978**, *5*, 91.

Gould, W. A.; Hair, B.; Baroudi, A. *Am. Potato J.* **1979**, *56*, 133.

Hammond, J. B. W.; Nichols, R. *J. Sci. Food Agric.* **1975**, *26*, 835.

Hansen, H.; Rumpf, G. *Acta Hortic.* **1974**, *38*, 321.

Hinds, M. K.; Kromer, G. W. In "Peanut—Culture and Uses"; American Peanut Research and Education Association: Stillwater, OK, 1973; Chapter 20.

Holley, K. T.; Hammons, R. O. *Res. Bull.—Ga. Agric. Exp. Stn.* **1968**, *32*.

Mason, M. E.; Newell, J. A.; Johnson, B. R.; Koehler, P. E.; Waller, G. R. *J. Agric. Food Chem.* **1969**, *17*, 728.

Muller-Thurgau, H. *Landwirtsch. Jahrb.* **1882**, *11*, 751.

Newell J. A.; Mason, M. E.; Matlock, R. S. *J. Agric. Food Chem.* **1967**, *15*, 767.

Oupadissakoon, E.; Young, C. T.; Mozingo, R. W. *Peanut Sci.* **1980**, *7*, 55.

Pattee, H. E.; Johns, E. B.; Singleton, J. A.; Sanders, T. H. *Peanut Sci.* **1974**, *1*, 57.

Perry, A. "1974 Profit Producing Peanut Practices"; Extension Service, NC State University, Raleigh, NC, 1974.

Reddy, N. N.; Sistrunk, W. A. *J. Food Sci.* **1980**, *45*, 682.

Rutherford, P. P.; Ali, N. A. *Ann. Appl. Biol.* **1977**, *85*, 159.

Ryall, A. L.; Lipton, W. J. "Handling, Transportation, and Storage of Fruits and Vegetables. Vol. 1, Vegetables and Melons"; Avi Publishing Co.: Westport, CT, 1972; Chapter 9.

Slay, W. O. *U.S., Agric. Res. Serv., South. Reg.*, [*Rep.*] **1976**, *ARS-S-81*, 1–8.

Smith, O. In "Potato Processing"; Talburt, W. F.; Smith, O., Eds.; Avi Publishing Co.: Westport, CT, 1967; Chapter 7.

Tharanathan, R. N.; Wankhede, D. B.; Raghavendra-Rao, M. R. *J. Sci. Food Agric.* **1975**, *26*, 749

Tharanathan, R. N.; Wankhede, D. B.; Raghavendra-Rao, M. R. *J. Food Sci.* **1976**, *41*, 715.

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