Effects of Storage Environment on Farmers Stock Peanut Grade Factors in an Aerated Warehouse in West Texas

P.D. Blankenship[1]*, G.M. Grice[2], C.L. Butts[1], M.C. Lamb[1], T.H. Sanders[3], B.W. Horn[1], and J.W. Dorner[1]

ABSTRACT

Temperature and relative humidity (RH) in an aerated warehouse in west Texas were monitored during storage of 1994 and 1995 crop farmer stock (FS) peanuts. Temperature and RH were measured at various positions throughout a vertical cross section of the peanut mass in the overspace and outside the warehouse. Data were collected at 1-hr intervals throughout storage. Peanut mass temperatures averaged 9.6 C during storage for the 1994 crop and 10.3 C for the 1995 crop. Relative humidity for the 1994 crop storage averaged 68.3 and 57.9% for the 1995 crop storage. Farmer stock grades were collected at warehouse loading and unloading for 10- to 12-t lots of peanuts stored in the warehouse (Wpnuts) and for samples (Spnuts) positioned at temperature and RH sensor locations. Wpnuts, in approaching equilibrium moisture with ambient RH, lost 2% moisture content both storage years. Spnuts lost 1.4% moisture content during storage of both crops. Percentage sound mature kernels (SMK) from Wpnuts decreased by 3.3% during 1994 crop storage and 6.6% during 1995 crop storage. Percentage SMK from Spnuts decreased 2.2 and 6.2% for the two storage years. Percentage sound splits (SS) for the Wpnuts increased 2.2% during 1994 crop storage and 4.2% during the 1995 crop storage. Percentage SS for Spnuts increased 2.4 and 6.1%, respectively. Changes in other grade factors were not consistent comparing percentage values for Wpnuts and Spnuts. Data indicate that maintaining grade and quality during FS peanut storage in west Texas will require knowledge of moisture content of peanuts placed into the warehouse and environmental monitoring in order to determine storage length. For 3- to 5-mo storage, it is recommended that FS peanuts have a moisture content close to 10% when placed into storage for peanuts to be above 7% when unloaded from the warehouse.

Key Words: Aeration, *Arachis hypogaea* L., quality, warehousing.

Peanut production is rapidly increasing in west Texas because of low disease risks and aflatoxin contamination during production, diminishing profit opportunities for peanuts in other parts of Texas, and decreasing profit opportunities in cotton production. From 1995 to 1998, peanut production in 21 counties of west Texas increased from 17,806 to 76,595 ha. Because of the lack of existing storage facilities in the area, most farmer stock (FS) peanuts produced in west Texas have previously been shipped to other locations for storage prior to shelling. During the 4 wk of the major part of harvest, excess demand for available trucks have made it increasingly difficult for shipping to other locations. Warehouse construction in the area is an obvious solution, but some shellers and warehousemen have generally considered the average ambient relative humidity to be too low (< 70%) during the storage season for good FS peanut storage. Warehouse construction also has been limited

[1]Agric. Eng., Agric. Eng., Agri. Eco., Microbio., and Microbio., respectively, USDA, ARS, Nat. Peanut Res. Lab., Dawson, GA 31742.
[2]V.P., Birdsong Peanuts, Gorman, TX 76454.
[3]Res. Pl. Physiol., USDA, ARS, NC St. Univ., Raleigh, NC 27695-7624.
*Corresponding author (email: pblankenship@nprl.usda.gov).

because of current decreasing profit margins in peanuts and concern regarding peanut moisture and quality maintenance during storage.

Previous research, conducted primarily in the Southeastern U.S., has shown effects of peanut moisture content and environmental conditions on quality of FS peanuts (1, 2, 3, 4, 7, 8, 9, 10). Low peanut moisture content has a destructive influence on shelling characteristics (1, 2). Moisture content of FS peanuts stored in low relative humidity environments may drop below 7% with an accompanying loss in marketable weight (1, 2, 8). Moisture loss is economically important since peanut quality and value are directly related to moisture content (10). At farmer marketing, the value of FS peanuts is calculated using Federal State Inspection Service grade factors (including moisture content), USDA-FSA Peanut Loan Schedules, and weight (10). In calculating farmer value, peanut kernel moisture content, which is usually above 7% at marketing, is adjusted to 7% and lot weight adjusted proportionally by the same percentage since weight and peanut moisture content are directly proportional. Moisture content and weight are not adjusted if moisture content is less than 7%. Thus, if moisture content is not maintained at or above 7% during storage, direct value loss can occur because of loss of purchased peanut weight ignoring potential quality damage. The objectives of this study were to measure the environment in an aerated FS peanut warehouse in west Texas during storage and determine the effects of the environment on grade factors, weight, and value.

Materials and Methods

Data were collected during two storage seasons to determine the extent of peanut moisture and quality loss during typical storage periods. The study was conducted cooperatively with Birdsong Peanuts, Southwest Div., Gorman, TX, during the 1994-95 and 1995-96 storage seasons. In 1994, Birdsong constructed a warehouse with an aeration system in Gaines County, TX to provide on-site storage at their buying point to reduce FS peanut transportation during harvest. Construction of additional warehouses by Birdsong would depend upon success of maintaining peanut moisture and quality during storage and continuance of the production increase in the area.

The warehouse was a steel frame, metal clad structure with a flat concrete floor, 118.3 m by 24.4 m. Side walls were 7.3 m high at the eaves with a 37° roof slope and an east-west orientation. Estimated capacity of the warehouse was 9072 t. The apex of the roof had a doghouse the length of the roof 3.7 m wide by 2.7 m high at the eaves with a 5° slope roof. Ten ridge vents were evenly spaced along the ridge of the doghouse roof. A partition was installed across the warehouse at 38.6 m from the east end dividing the storage area into two bins, one with approximately 2/3 of the warehouse volume and the other with 1/3. This study was conducted in the larger bin.

The warehouse contained an aeration system composed of six 2.36-m^3/sec fans which evacuated air from inside the warehouse through three 103.6 m × 0.9 m × 0.3 m air ducts embedded in the concrete floor. Each duct was connected to the air entry of two fans placed on opposite sides of the warehouse which allowed air from inside of the warehouse to be pulled down through the peanuts and to be evacuated to the outside. Tops of the ducts were perforated allowing air entry. One of the air ducts was located in the center of the width and length of the warehouse and each of the others was spaced 6.1 m from the center duct toward the warehouse side. Fan operation was controlled electronically utilizing relative humidity (RH) sensors. All fans were switched on by a single sensor located in the overspace above the peanuts midway of the large warehouse bin when the RH rose to 70% or higher. Relative humidity sensors were located for each fan in the supply ducts that switched off each fan individually if the RH reached less than 70% in the duct just prior to the fan. Seventy percent was chosen as the control RH since peanut kernel equilibrium moisture content is 7-7.5% at this humidity (1).

Temperatures and RH were measured and recorded hourly within the peanut mass, in the warehouse overspace, and for ambient conditions. Measurements within the warehouse and peanut mass were made at a vertical plane, midpoint cross section of the large storage bin. Temperature and RH sensor locations are shown in Fig. 1. Phys-Chemical Research Corp. PCRC-11 humidity sensors were used to measure RH at all locations except floor level. ANSI type T thermocouples were used to measure temperature. A Campbell Scientific, Model CR-7, data logger collected and stored data on cassette tapes during the storage seasons.

Runner-type peanuts were stored in the warehouse during both years of the study. The peanuts were harvested by area farmers, field dried, transported to the buying point in 20- to 25-t lots, sampled, and graded by the Texas Federal-State Inspection Serv., and purchased by Birdsong. The peanuts from each lot were then loaded into an 81.3-t/hr warehouse supply elevator through a dump pit elevated to the warehouse doghouse level and run across two vibrating screens with 0.635-cm openings for sand removal, transported into the warehouse with a horizontal conveyor belt, fed onto a 100-ft lengthwise movable drag belt in the doghouse, and dropped into the warehouse bin for storage.

The warehouse was filled beginning 10 Oct. 1994 and 12 Oct. 1995. Ninety-nine percent of the peanuts were moved into the warehouse both years by 30 Nov. For each storage period, 246 peanut samples, each weighing 3 kg, were extracted from a single combine basket of field-dried farmer stock peanuts (approximately 1134 kg) which had been dumped into a hopper-bottom grain trailer. Samples were randomly extracted from the trailer into mesh bags through the trailer discharge gate. Four samples were identified for each of the 41 sensor locations. A 300- to 400-g subsample was manually dipped from the top of one of the samples for initial moisture determination with a Steinlite Model PT-2 moisture meter. The remaining peanuts in the opened bag were transported to and graded by the Texas Federal-State Inspection Serv. in Gorman, TX. The remaining three samples (in mesh bags) of each four were placed at a sensor location during warehouse filling. The samples remained in place until the warehouse was unloaded.

For 1995, unloading began on 12 Apr. and was completed on 31 May. For 1996, unloading began on 21 Feb. and was completed on 31 May. The samples at the sensor locations were removed as uncovered and transported to and graded by the Texas Federal-State Inspection Serv. in Gorman, TX. A 300- to 400-g subsample was manually dipped from one bag for final moisture determination.

Tabular comparisons of means presented in the manuscript were obtained using the Duncan's New Multiple

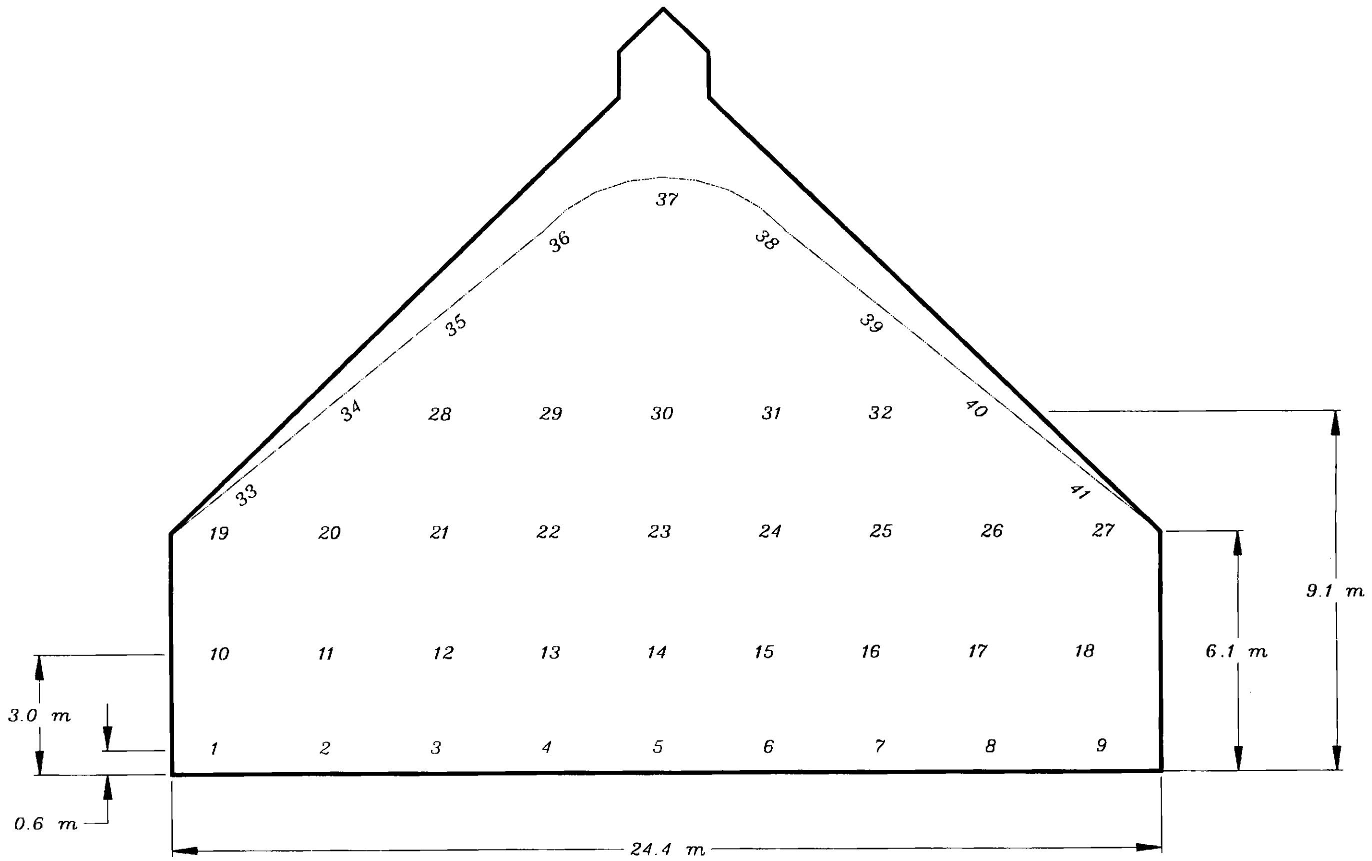

Fig. 1. Cross section of warehouse indicating numbered sensor and sample locations within the peanut mass.

Range Test option of PROC GLM in SAS (11). Curves describing environmental conditions during the tests were generated using PROC GPLOT in SAS (11).

Results and Discussion

Average daily temperature curves for the peanut mass (average of thermocouple readings within peanuts), warehouse overspace, and ambient followed similar trends for both storage periods (Figs. 2,3). The various average temperatures for the 1995-96 period were significantly higher than the 1994-95 period but yearly mean differences were less than 1 C (Table 1). The peanut mass temperature mean for the 1995-96 storage period was 0.7 C higher than for the 1994-95 storage period: the overspace, 0.6 C higher; and ambient, 0.4 C higher (Table 1). Though statistically significant, differences in temperatures during the two storage periods were not considered large enough to appreciably affect peanut moisture or quality in comparing environmental conditions between the two storage periods.

Average daily RH curves for the peanut mass, warehouse overspace, and ambient also indicated similar fluctuations for both storage periods (Figs. 4,5) but at different magnitudes (Table 1). The peanut mass RH mean for the 1995-96 storage period was 10.4% lower than for the 1994-95 storage period: the overspace, 11.9% lower; and ambient 11.9% lower (Table 1). During the 1994-95 storage period, the warehouse overspace RH was high enough for aeration (above 70%) 26% of the time. However, this only occurred 13.4% of the time during the 1995-96 storage period. After 1 March 1995, the overspace RH peaked above 70% only one time and none after early February in 1996. Because the 70% control point limited aeration, peanut moisture contents both years were equilibrating downward towards moisture below 7% which is detrimental to FS grades and accompanying value loss (1, 2, 8). The effects of RH were evident in comparing peanut moisture data and other grade factors.

The moisture content mean of the peanuts used for warehouse loading for the 1994-95 storage period averaged 9.2% moisture content (Table 2). The RH of the peanut mass was 73-74% on 30 Oct. 1994 (Fig. 4). At unloading, the peanuts had equilibrated to 7.2% moisture content with RH averaging 67-68% the last month of storage (Fig. 5). Peanuts for warehouse loading for the 1995-96 storage period data averaged 8.7% moisture content with a mass RH of 63-65% RH on 30 Oct. 1995 (Table 2; Fig. 5). At unloading, the kernels had equilibrated to 6.7% moisture content with a RH averaging 54-56% the last month of storage (Fig. 4). The 1994-95 peanut samples averaged 8.5% moisture content at loading and 7.1% at unloading (Table 3). Peanut samples for the 1995-96 storage period averaged 7.1% moisture content at loading and 5.7% at unloading (Table 3). Unloading peanut kernel moisture contents for both storage periods for the peanut mass and peanuts in the samples are in close agreement with previously reported research

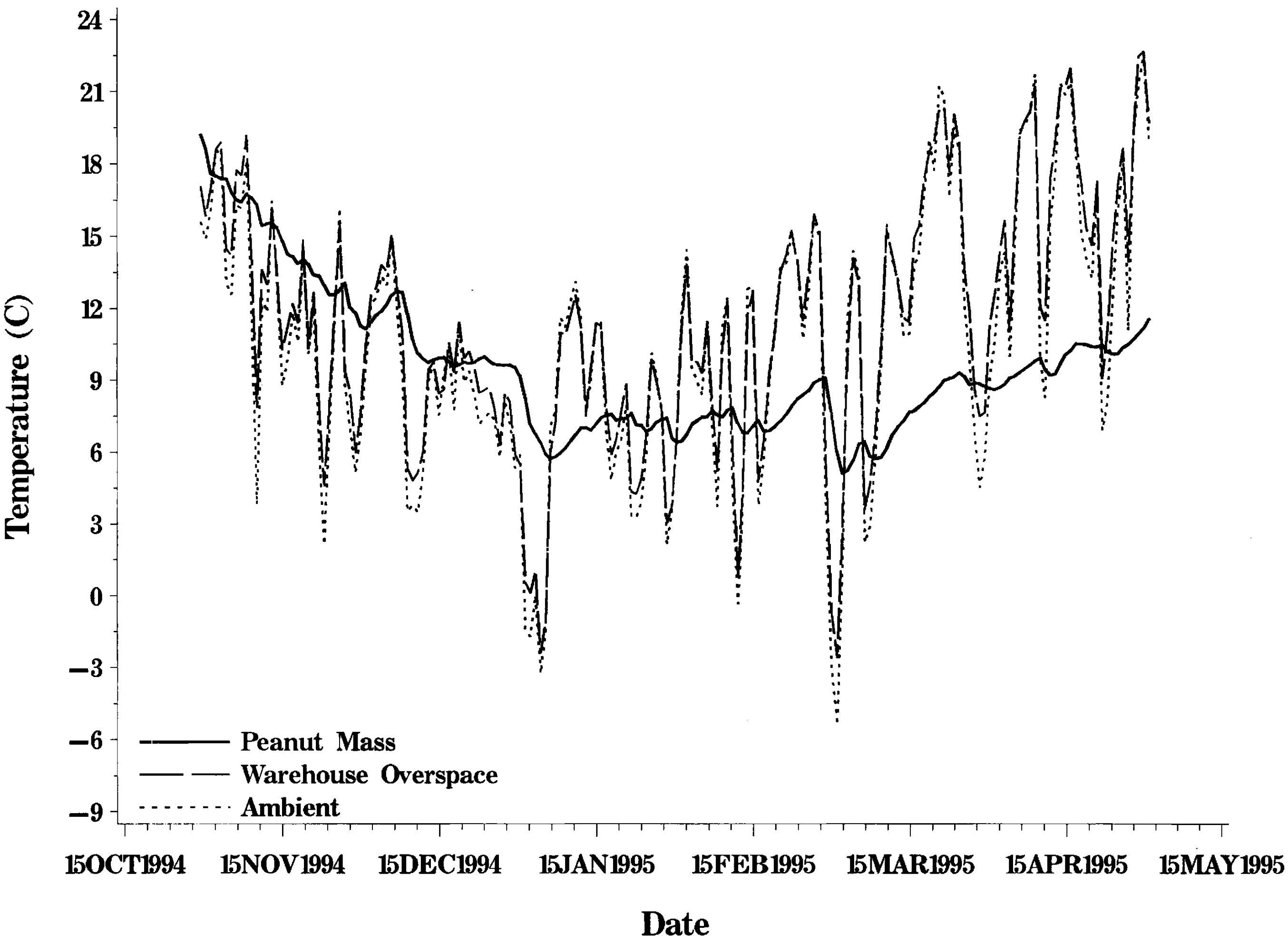

Fig. 2. Mean daily temperatures of the peanut mass, warehouse overspace, and ambient conditions during storage of farmer stock peanuts in an aerated warehouse in west Texas during the 1994-95 storage period.

on peanut moisture relationships with storage environment (8, 9) and peanut equilibrium moisture relationships with RH (1). Changes in grade factor means other than moisture content also were indicated in the data for both storage periods.

Aspergillus flavus was not detected during grading of any samples at warehouse loading or unloading. Percentage SMKs decreased significantly both years during storage for the peanuts used to fill the warehouse (Wpnuts) and for peanuts in the positioned samples (Spnuts) (Tables 2, 3). During the 1994-95 storage period, the SMK mean for Wpnuts was 3.3% higher at warehouse loading than at unloading (Table 2). The SMK mean at loading was 6.6% higher at loading than at unloading for the 1995-96 storage period. Similarly, SMK means for the Spnuts were 2.8% higher at loading for the 1994-95 storage period than at unloading and 6.2% higher at loading for the 1995-96 storage period (Table 3). Sound splits means at loading and unloading indicated an opposite relationship with SMK means. During the 1994-95 storage period, SS means for the Wpnuts were significantly higher by 2.2% than at unloading and 4.2% for the 1995-96 period (Table 2). Sound splits means for the Spnuts also were significantly higher at unloading than loading by 2.4% in the 1994-95 storage period and 6.1% in 1995-96. Changes in SMK and SS were attributed to changes in moisture content during storage, which is in agreement with previously reported research (1, 2). Sound mature kernel percentages decrease with moisture content because kernels separate into two halves (splits) which increases percentage splits.

Differences in LSK means at loading and unloading were not consistent for Wpnuts between storage periods. Mean LSKs were 0.6% higher at loading than at unloading for 1994-95 storage period and 4.3% lower for the 1995-96 period (Table 2). Since the peanuts had been handled through an elevator and dropped into the warehouse at loading, and removed from the warehouse with a front end loader and belt conveyor at unloading, increases in LSKs were expected from handling damage (5, 6). Mean LSKs for peanuts in the positioned samples were not significantly different at loading and unloading for either storage period. Since the samples were positioned and removed by hand, LSK differences were not expected in these samples. For both storage periods, foreign material (FM), other kernels (OK), and damaged kernels (DK) increased in peanuts used to fill the ware-

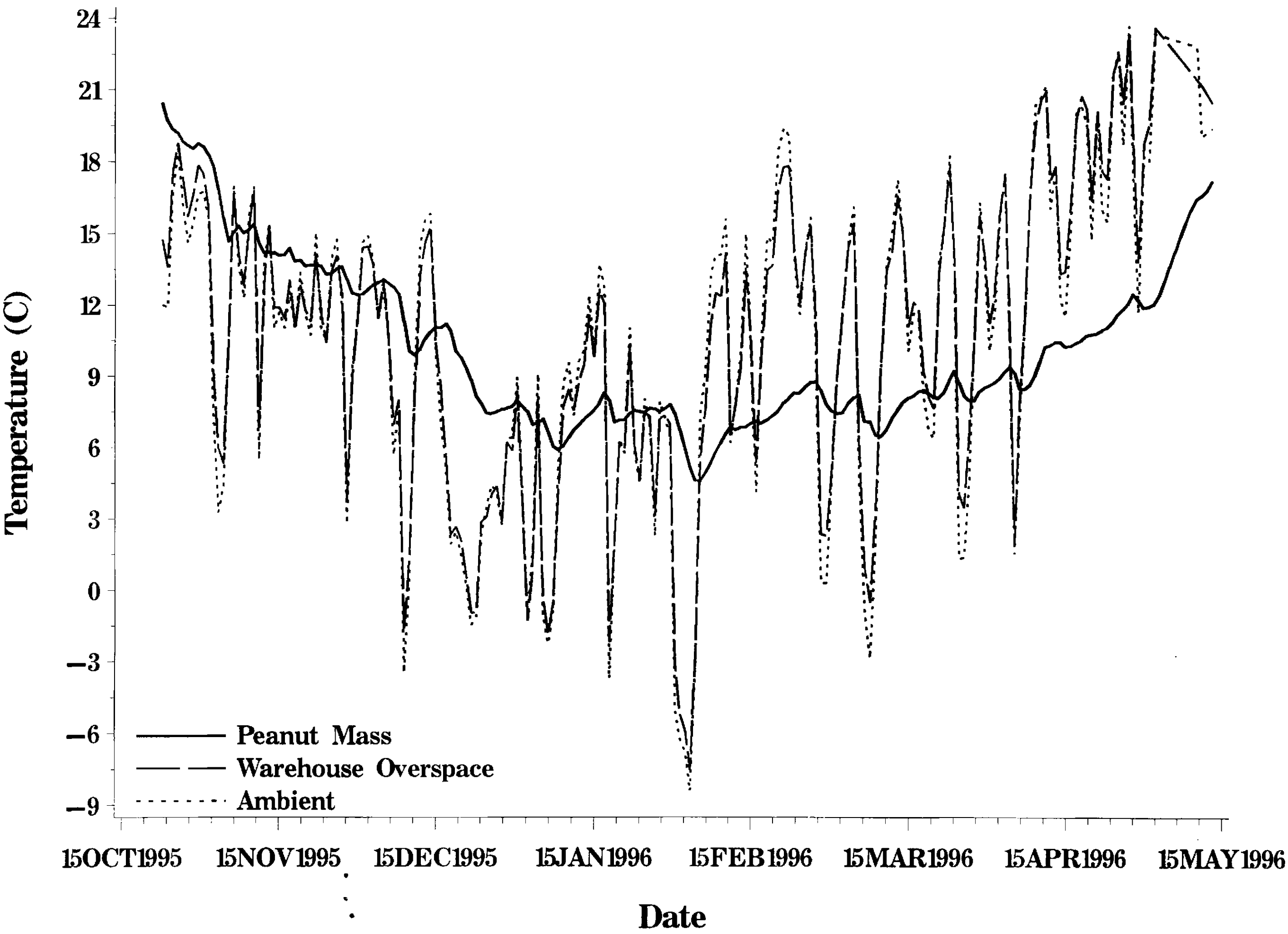

Fig. 3. Mean daily temperatures of the peanut mass, warehouse overspace, and ambient conditions during storage of farmer stock peanuts in an aerated warehouse in west Texas during the 1995-96 storage period.

Table 1. Ambient, overspace, and peanut mass temperature and relative humidity means during storage of farmer stock peanuts in an aerated warehouse in west Texas 1994-95 and 1995-96 storage periods.

Variable	Storage period 1994-95	1995-96
Ambient temperature[a] (c)	10.6 d	11.0 c
Overspace temperature (c)	11.4 b	12.0 a
Peanut mass temperature (c)	9.6 f	10.3 e
Ambient relative humidity[b] (%)	50.7 d	38.8 f
Overspace relative humidity (%)	51.3 c	39.4 e
Peanut mass relative humidity (%)	68.3 a	57.9 b

[a]Temperature means followed by the same letter are not significantly different ($P \leq 0.05$) by Duncan's new multiple-range test.

[b]Relative humidity means followed by the same letter are not significantly different ($P \leq 0.05$) by Duncan's new multiple-range test.

house (Table 2). Sound mature kernels + SS and total kernels decreased. None of these grade factors for the positioned samples were significantly different when comparing loading versus unloading for the storage pe-

Table 2. Mean grade factors and value/t of the farmer stock peanuts at warehouse loading and unloading stored during the 1994-95 and 1995-96 storage periods.

	Storage period[a]			
	1994-95		1995-96	
Grade factor	Load	Unload	Load	Unload
Moisture content (%)	9.2 a	7.2 c	8.7 b	6.7 d
Loose shelled kernels (%)	3.5 b	2.9 c	2.8 c	7.1 a
Foreign materials (%)	4.0 c	4.4 b	4.3 bc	5.9 a
Sound mature kernels (SMK) (%)	67.9 a	64.6 c	66.3 b	59.7 d
Sound splits (SS) (%)	6.6 d	8.8 b	7.4 c	11.6 a
SMK + SS (%)	74.4 a	73.3 c	73.7 b	71.4 d
Other kernels (%)	3.9 d	4.3 b	4.1 c	4.9 a
Damage (%)	0.3 b	0.4 a	0.1 d	0.2 c
Total kernels (%)	78.6 a	78.1 b	77.8 c	76.5 d
Value/t[b] ($)	569.65 a	563.12 b	566.89 a	527.91 c

[a]Means in each row followed by the same letter are not significantly different ($P \leq 0.05$) by Duncan's new multiple-range test.

[b]Values calculated utilizing the quota price from the 1999 Peanut Loan Schedule.

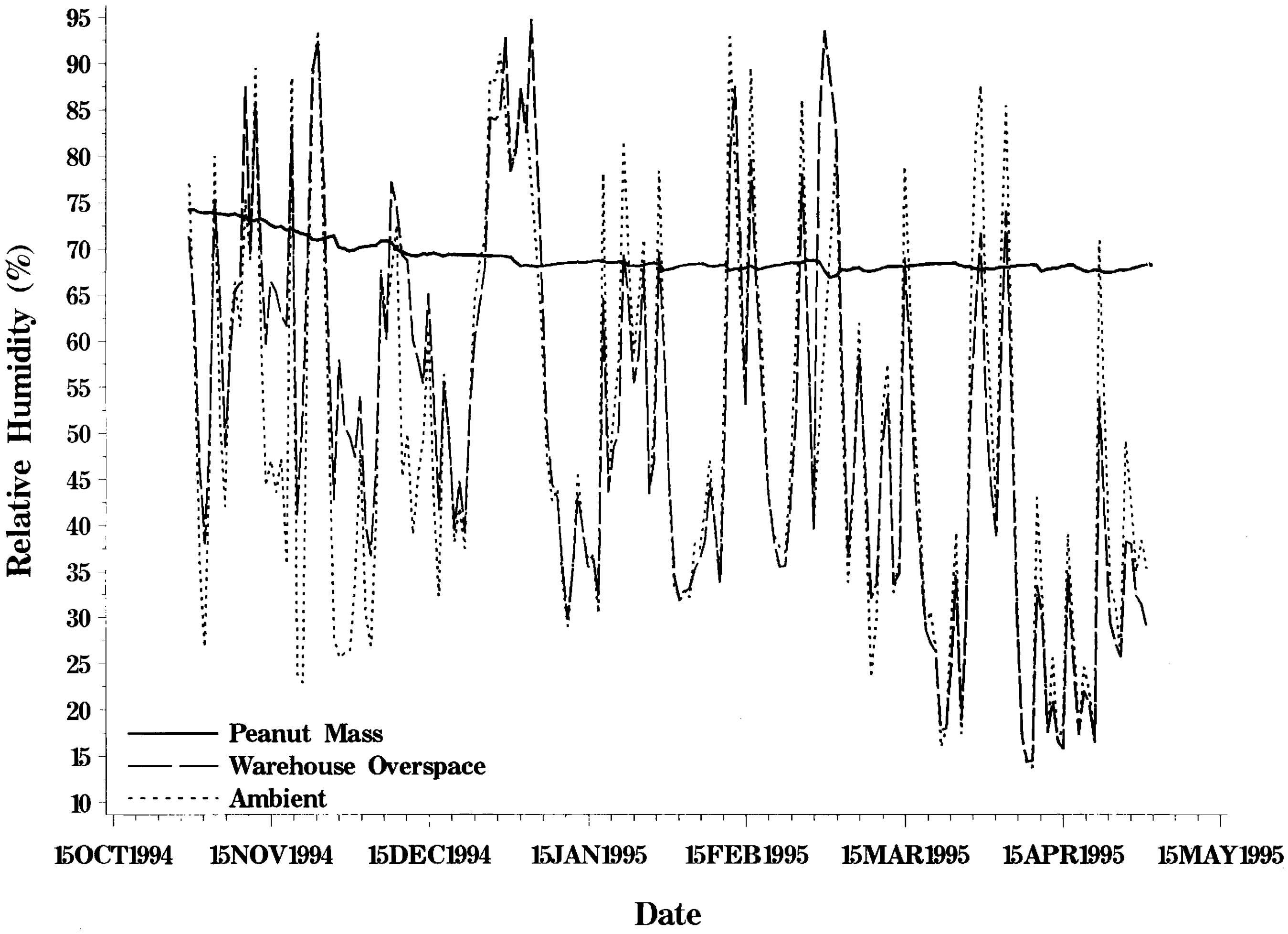

Fig. 4. Mean relative humidity of the peanut mass, warehouse overspace, and ambient conditions during storage of farmer stock peanuts in an aerated warehouse in west Texas during the 1994-95 storage period.

riods (Table 3). Explanations were not apparent for inconsistencies in the relationships of the above grade factor means at warehouse loading and unloading for peanuts used to fill the warehouse and peanuts used in the positioned samples.

Warehouse loading value/t means were significantly higher than at unloading for the peanuts used to fill the warehouse each storage season (Table 2). Values were calculated utilizing the quota price from the 1999 Peanut Loan Schedule. Loading value/t means were not significantly different by storage period (Table 2). Unloading value/t means were significantly lower than loading value/t means for both storage periods. Also, the 1995-96 unloading mean was significantly lower than the 1994-95 unloading mean. The 1994-95 value/t mean was \$6.53/t higher at warehouse loading than at unloading. The value/t mean at loading was \$38.98/t higher at loading than at unloading for the 1995-96 storage period. Total weight of the peanuts loaded into the warehouse from the 1994 crop was 9268 t. Total weight of the peanuts unloaded after storage was 9175 t. For the 1995 crop, 8461 t were loaded and 8120 t unloaded. Based on mean FS grades and weights of peanuts loaded and unloaded for the warehouse both years, the total value of the FS

Table 3. Mean grade factors of the positioned samples of farmer stock peanuts at warehouse loading and unloading during the 1994-95 and 1995-96 storage periods.

	Storage period[a]			
	1994-95		1995-96	
Grade factor	Load	Unload	Load	Unload
%				
Moisture content	8.5 a	7.1 b	7.1 b	5.7 c
Loose shelled kernels	3.1 b	2.7 b	4.3 a	3.6 ab
Foreign materials	1.0 b	1.0 b	3.0 a	2.8 a
Sound mature kernels (SMK)	73.9 a	71.1 b	69.0 c	62.8 d
Sound splits (SS)	3.1 d	5.5 c	6.7 b	12.8 a
SMK + SS	77.0 a	76.7 a	75.7 b	75.6 b
Other kernels	2.1 b	2.2 b	4.4 a	4.5 a
Damage	0.2 a	0.3 a	0.0 b	0.0 b
Total kernels	79.3 b	79.1 b	80.0 a	80.2 a

[a]Means in each row followed by the same letter are not significantly different ($P \leq 0.05$) by Duncan's new multiple-range test.

moisture contents as close to 10% as possible for warehouse loading; monitoring environmental conditions

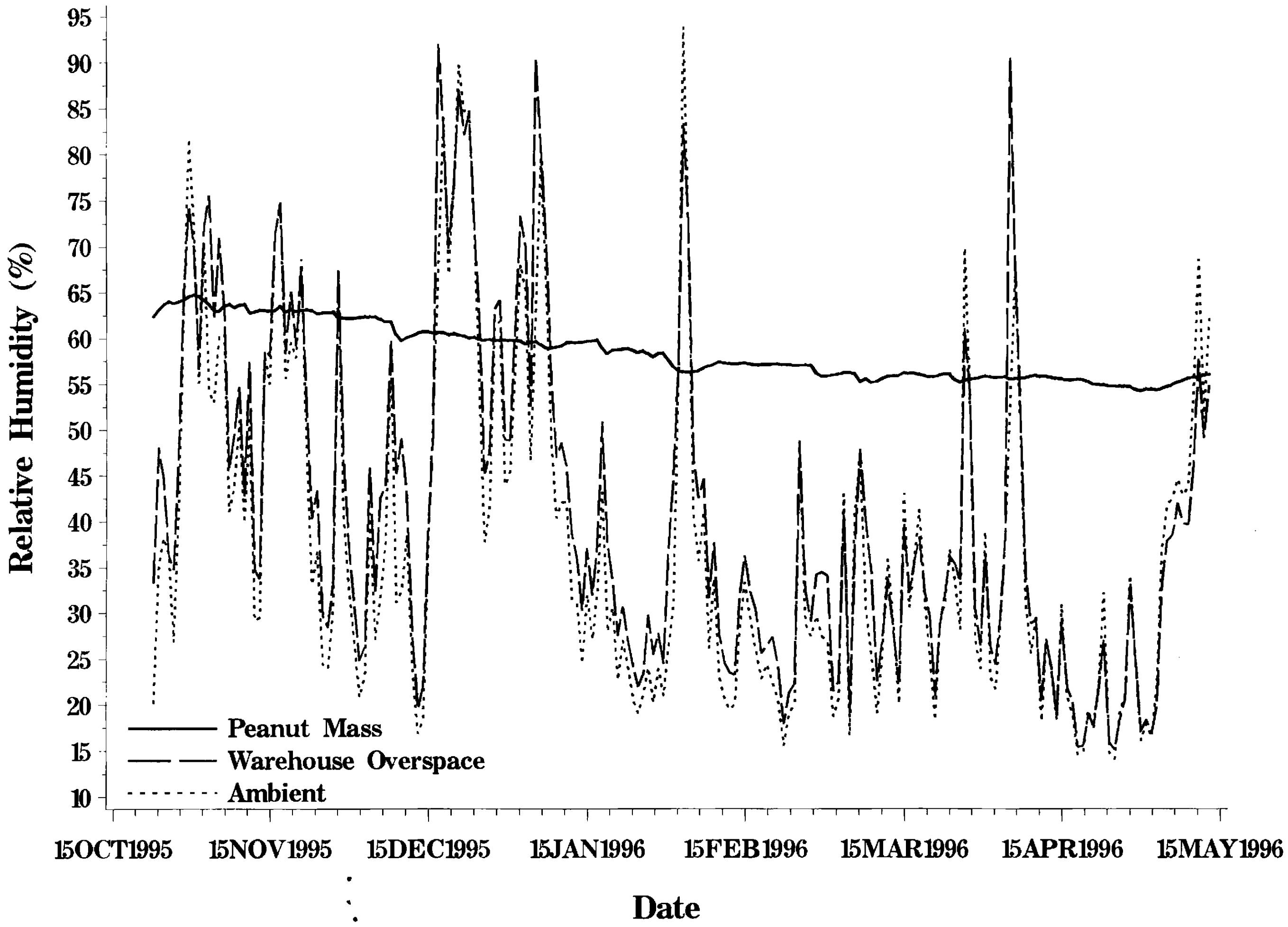

Fig. 5. Mean relative humidity of the peanut mass, warehouse overspace, and ambient conditions during storage of farmer stock peanuts in an aerated warehouse in west Texas during the 1995-96 storage period.

peanuts stored in the warehouse decreased $112,890 (2.1%) during the 1994-95 storage period and $509,827 (10.6%) during the 1995-96 period. Value change differences occurred primarily from moisture loss and accompanying decreases in SMK and increases in FM, SS, OK, and damage (Table 2). The 1995-96 storage period also had a significant increase in LSK and an average moisture less than 7% which resulted in approximately $216,000 of the calculated loss.

Conclusions

Temperatures within the peanut mass during both storage periods were similar to previously reported temperatures and were apparently within ranges considered satisfactory for good FS storage (8, 9, 10). However, RH was questionable for satisfactory storage indicating the need for management strategies to prevent excessive peanut moisture loss. Aeration may be a strategy for assistance in peanut moisture management during storage in west Texas; however, data presented indicate aeration potential may be extremely variable between storage seasons and very limited during certain periods in a storage season. Required strategies for managing west Texas storage should include selecting peanuts with during storage; and, possibly most important, basing length of storage on loading moisture content and environmental history during storage.

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