Quality and Economic Evaluation of Peanut Stored in Modular Containers[1]

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ABSTRACT

Handling problems at buying/drying points have significantly increased with the increased harvesting rate of the 4-, 6-, and 8-row combines. Peanuts (*Arachis hypogaea* L.) can be cured and dried, stored, and moved to the shelling plant when placed in the modular container (box) at the field location. Boxes sized 1.8 m deep × 2.3 m wide × 7.3 m long will hold about 10 Mg of peanuts with two boxes making a semitrailer load. In 1995 and 1996, standard 4.3-m peanut wagons and 4.3-m boxes were used to study a) changes in peanut moisture, b) handling concerns of boxes, and c) the economic feasibility of handling peanuts in boxes. Peanut moisture content decreased from about 10.3 to 6.2% during the two storage periods of 140 and 160 d. Differences in temperature and relative humidity caused the average moisture content to decrease from 9.6 to 7.5% in 70 d during 1995 compared to a drop from 9.5 to 7.5% in 140 d during 1996. Maximum and minimum temperatures in the top 15 cm lagged behind the ambient temperature by 6.4 and 4.3 hr, respectively. Daily average temperatures and relative humidities in the paired boxes and wagons were similar. Relative humidity in the middle of the boxes and wagons did not fluctuate with ambient humidity. Transferring peanuts by an elevator failed to simulate warehouse system handling damage. The economic analysis, after adjusting for reduced shrink loss and handling loss, showed an on-farm operation cost of \$19.54/yr/Mg for the box system concept compared to \$19.98/yr/Mg for the current wagon-warehouse system. For a buying point operation, the cost was \$9.80/yr/Mg for the box system concept compared to \$9.93/yr/Mg for the wagon-warehouse system. The two systems are approximately equal in total cost.

Key Words: *Arachis hypogaea* L., container, moisture content, storage, temperature.

Peanut (*Arachis hypogaea* L.) harvesting rates have significantly increased with the use of the 4-, 6-, and 8-row peanut combines. A two-row peanut combine can harvest approximately 5 ha/d compared to 16 ha/d for a 6-row combine. Since 1995, 6-row machines comprise approximately one-third of all new peanut combine sales. No two-row combines are currently produced for sale in the U.S. (M. Mathis, pers. commun., 1997). Increases in harvesting rates have created field handling, curing, and storage problems. A faster handling system is needed to move peanuts from large combines to storage or shelling locations.

Using the same modular container (box) to load peanuts in the field, move them through the curing process, and store them offers many advantages over the current handling system. Advantages of using a box system concept include a) faster movement of the peanuts out of the field, b) reduced highway transport liability, c) more accurate grower and varietal identification, d) less handling damage, and e) more accurate historical data for value added product information.

Disadvantages include higher capital costs for the boxes, highway and handling equipment, and larger drying facilities and equipment. Costs may be reduced if existing storage facilities are modified to accommodate the box system.

Currently, peanuts cured to a moisture content of 11% on the top layer can be 3 to 4% w.b. higher than the bottom of the 1.4-m depth in a wagon (Cundiff *et al.*, 1991). Peanuts harvested with a wide variation among individual kernel moisture content may need to be cured to less than 11% (Smith and Davidson, 1982; Smith *et al.*, 1985; Dowell and Lamb, 1991) for safe storage unless the pods are shelled soon after curing and drying. Using "half-trailer" size containers covered immediately after curing (Wright *et al.*, 1996b) showed the peanut moisture content changed little throughout a 16-wk storage period. If wagons are stored in open sheds and not covered, the peanut moisture content will decrease to an equilibrium moisture content controlled by the ambient temperature and relative humidity (Beasley and Dickens, 1963).

The box system concept is similar to the current drying wagon without running gear, and is longer and deeper (7.3 m long × 2.3 m wide × 1.8 m deep) to hold about 10 Mg of runner-type peanuts (Wright *et al.*, 1996a). The box can be moved from the field to the buying location with a hook-lift truck, placed on the dryer facility, moved about the buying point with a prime mover for grading and storage. Two units can be transported on the same semitruck from the storage to the processing location requiring less loading and unloading time.

The purpose of this study was a) to monitor temperature and relative humidity in wagon and modular container (box) along with changes in peanut moisture content, b) assess handling problems associated with large boxes, and c) compare the cost of handling peanuts in boxes from the field to the sheller/processor location with the conventional wagon drying and warehouse system.

Materials and Methods

A 2-yr study was conducted using runner-type peanuts grown in Terrell, Lee and, Webster counties in southwest Georgia. Three 4.3-m wagons and boxes were used each

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year. The wagons and boxes were filled in the field with windrow dried peanuts harvested with standard 2- or 4-row combines. A wagon and box were paired for the filling, curing, and storage operations. In 1995, the peanuts in the wagon units were unloaded and reloaded through an elevator-dump pit to simulate handling damage that may occur while loading into a warehouse.

The boxes were constructed the same as standard wagons without a running gear. Two I-beam skids in place of the running gear allowed the boxes to be handled with a tilt-roll truck for transport. The boxes were set on the ground during drying and storage. Box or wagon size was 4.3 m long × 2.4 m wide × 1.3 m deep with a 23-cm deep air plenum under a perforated floor. Capacity of the box or wagon was about 4.5 Mg (7% w.b. moisture content).

All wagons and boxes were instrumented (Fig. 1) for monitoring temperature and relative humidity at three levels. Data was collected from the initiation of curing throughout the 20-wk storage period; however, only the data collected during the storage period are presented here. Holes were drilled at three depths on two sides to permit sampling with a 1.2-m moisture probe. Samples were collected at selected times throughout the storage period.

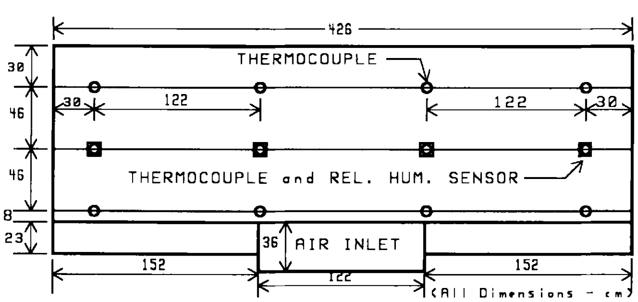

Fig. 1. Side view showing position of temperature and relative humidity sensors in the wagons and boxes.

Twelve thermocouples (ANSI Type T) were placed at three depths on two lines equally spaced across the box and wagon (Fig. 1) and four CSI207 humidity sensors were placed at the mid-level thermocouple position to measure relative humidity. A Campbell Scientific CR-7 data logger scanned the sensors every minute and logged the data every 15 min. Four sensors were averaged for each depth to provide readings at the top (30 cm), middle (76 cm), and bottom (122 cm) of the boxes and wagons.

Peanuts were dried with conventional dryer units controlled by a setpoint algorithm (Butts and Wright, 1996) developed from the standard recommended curing and drying conditions (Young *et al.*, 1982). This algorithm required a drying period slightly longer than used by commercial operators. Peanuts were graded according to standard FSIS procedures and stored in an open shed after curing. At the end of the 20-wk storage period, each box and wagon was sampled using a FSIS pneumatic sampler. All peanuts were dumped at the buying location when the storage period ended.

Results and Discussion

The paired wagon and box were filled in the field between 14 Sept. and 22 Sept. 1995 and 20 Sept. and 26 Sept. 1996 (Table 1). Kernel moisture contents (GAC moisture meter) at harvest ranged 16 to 22% in 1995 and 10 to 18% in 1996. Kernel moisture content difference between years reflects the weather conditions during the harvesting season. In 1995, boxes and wagons were cured to a moisture content (Dickey-john GAC II moisture meter) ranging between 10.1 and 12.4% (Table 1). The grade moisture content ranged between 9.0 and 10.3%, which was within the acceptance range for purchase of farmers stock peanuts and storage in a warehouse (PAC, 1996). In 1996, the cured moisture content ranged from 9.2 to 10.3% and the grade moisture content ranged from 8.9 to 10.2%.

At the end of storage, the peanut moisture content ranged between 6.2 and 7.0% for 142 to 149 d in storage, respectively during 1995 (Table 1). In 1996, the moisture content was 6.3 to 6.6% for 172 to 175 d of storage, respectively. The decrease of kernel moisture content with time for 1995 and 1996 are presented in Figs. 2 and 3, respectively. The fluctuation of moisture readings at each sampling time can be attributed to sampling error. In 1995, peanuts collected with a probe through port holes in the side wall at the top, middle, and bottom depths were pooled for the moisture sample. In 1996, the moisture sample was collected by probing the wagons and boxes from the top several times and pooling the peanuts. Kernel moisture content decreased to 7.0% in about 70 d in 1995 compared to about 140 d in 1996. The longer period for 1996 was attributed to the greater variation in single kernel moisture contents and different weather conditions for 1995 and 1996. These are two weather factors that warehouse operators have to consider if they are going to deliver peanuts to the shelling plants at moisture content levels conducive to good shellouts.

Average hourly temperatures at three depths in the wagons and boxes responded to the ambient tempera-

Table 1. Harvest dates and moisture contents for peanuts stored in wagons and boxes for 1995 and 1996.

Container no.	Harvest date	Moisture content Field	Cured	Grade	Storage
		% w.b.			
		1995			
Wagon 1	14 Sept.	19.0	11.8	9.5	6.2
Box 5	14 Sept.	18.9	10.9	9.5	6.3
Wagon 2	19 Sept.	18.8	12.4	10.3	6.2
Box 6	19 Sept.	16.9	11.3	10.3	6.6
Wagon 4	22 Sept.	22.0	10.1	9.0	6.9
Box 7	22 Sept.	20.9	10.6	9.1	7.0
		1996			
Wagon 1	20 Sept.	16.7	9.4	9.0	6.4
Box 5	20 Sept.	17.9	9.0	8.9	6.3
Wagon 2	24 Sept.	14.8	10.3	9.8	6.5
Box 6	24 Sept.	14.9	10.1	9.1	6.6
Wagon 4	26 Sept.	10.6	10.0	10.2	6.6
Box 7	26 Sept.	10.7	9.2	9.7	6.5

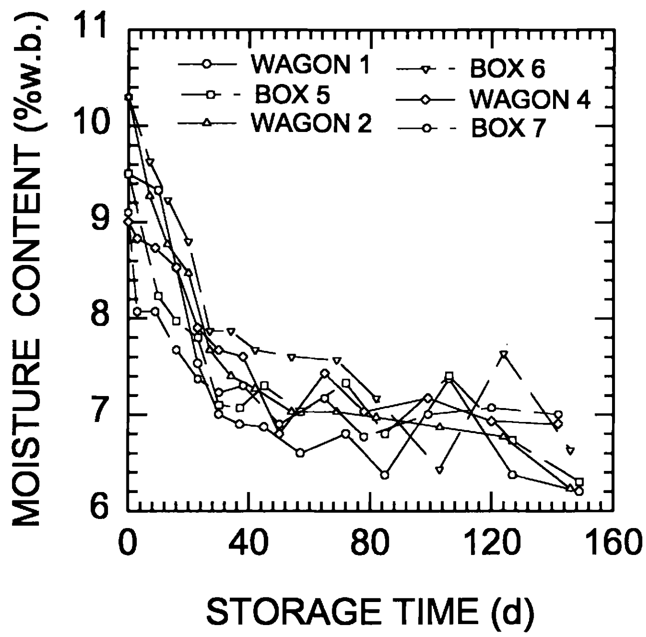

Fig. 2. Moisture content of peanut kernels for the 1995 storage season (starting 15 Sept. 1995).

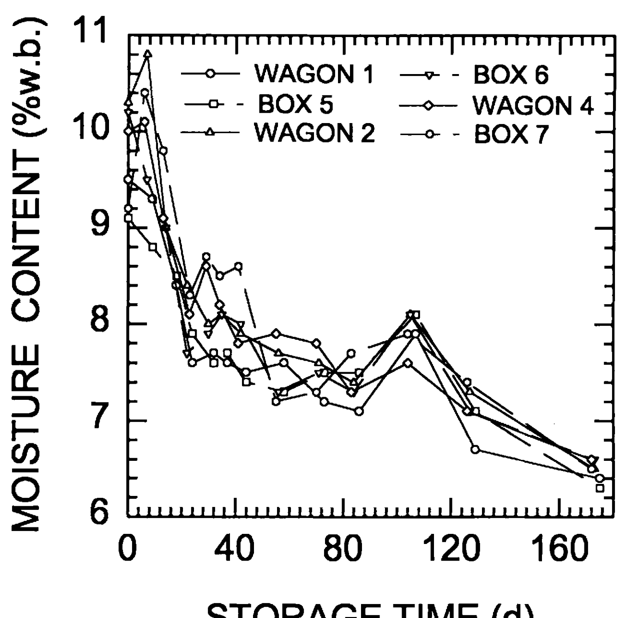

Fig. 3. Moisture content of peanut kernels for the 1996 storage season (starting 22 Sept. 1996).

ture with slightly different patterns. The middle and bottom temperatures (Fig. 4) fluctuated less than the top temperature with changes in the ambient temperature. The top maximum temperature lagged the ambient temperature about 6.4 hr and, the top minimum temperature lagged about 4.3 hr. This indicates that the temperature in a mass of peanuts changes more gradually with the outside conditions below a depth of about 30 cm. The middle and bottom temperatures measured in 1995 (Fig. 4) indicate about 500 hr, or 20 d, were

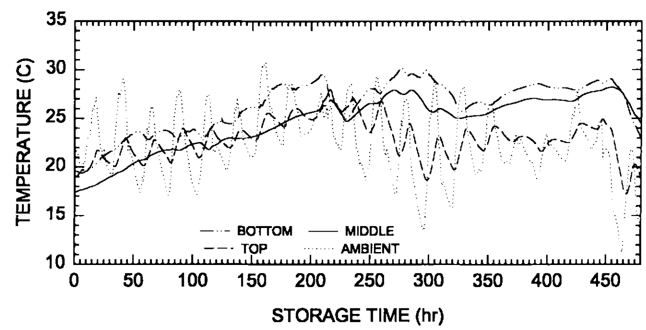

Fig. 4. Average hourly temperatures for the top (30 cm), middle (76 cm), and bottom (120 cm) depths in box 6 with the ambient temperatures for the 1995 storage season.

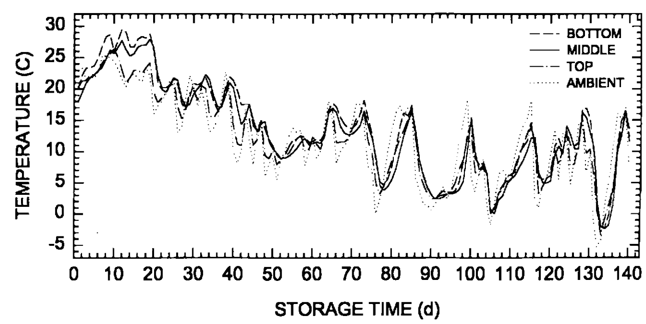

Fig. 5. Average daily temperatures for the top (30 cm), middle (76 cm), and bottom (120 cm) depths in box 6 with the ambient temperatures for the 1995 storage season.

required to get the excess heat out of the peanut mass in 1995-96.

The relation of the average daily temperature for the top, middle, and bottom depths for box 6 to the ambient temperature is shown in Fig. 5 for the 1995 storage season. After the cool down period of about 20 d, temperatures at all three depths followed the ambient temperature. Similar results (not shown) were observed for all wagons and boxes for both years.

Average daily temperatures for the middle level of box 6 and wagon 2 (Fig. 6A,B) show similar responses to ambient temperature for both storage seasons. Although not shown, the temperatures for all boxes and wagons showed similar responses which indicated there were no differences between boxes and wagons. In general, the 1995 ambient temperature (Fig. 6A) was warmer for the first 40 d and cooler for the remaining storage time compared to the ambient temperature for the 1996 season (Fig. 6B). The cooler temperature at the beginning of storage in 1996 helped to reduce the temperature of the peanut mass (Fig. 5).

Daily average relative humidity (Fig.7A,B) at the middle level of box 6 and wagon 2 were essentially equal throughout the two storage seasons. In 1995 (Fig. 7A), the average daily humidity ranged from 85% at the beginning of storage to about 60% at the end of storage. In 1996 (Fig. 7B), it ranged from 75 to 85% for the entire season. In comparison, the ambient relative humidity averaged higher in 1995 than in 1996. As mentioned earlier, the kernel moisture content is influ-

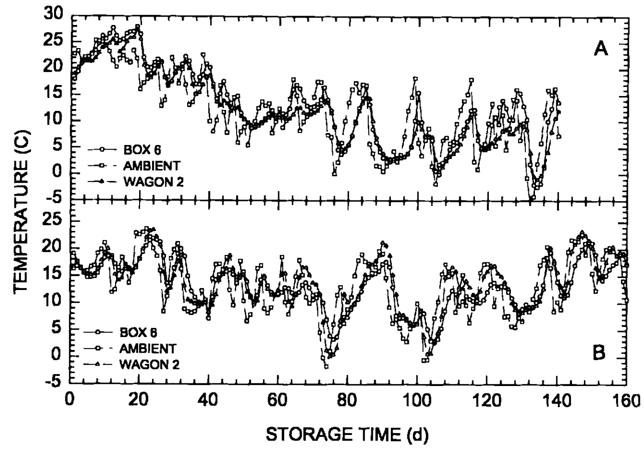

Fig. 6. Average daily temperatures for the middle depth (76 cm) of box 6 and wagon 2 with the ambient temperatures for the 1995 (A) and 1996 (B) storage seasons.

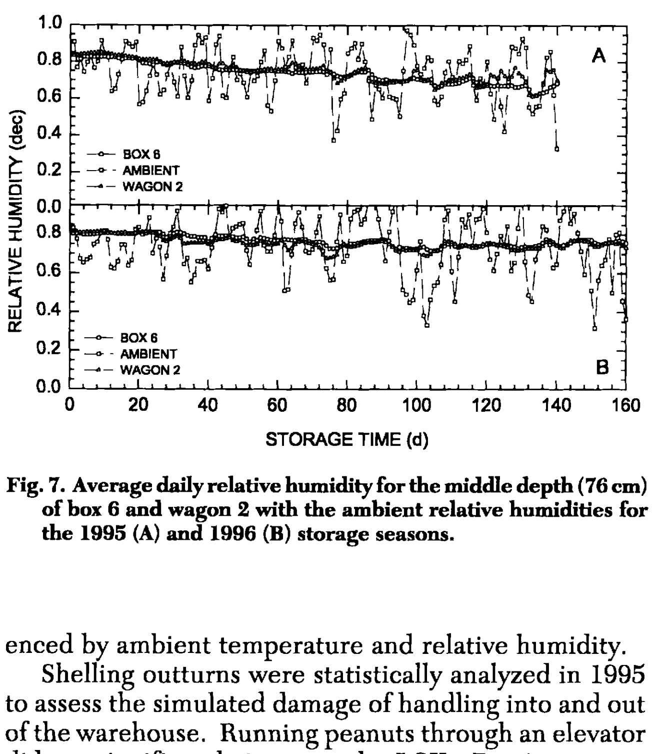

Fig. 7. Average daily relative humidity for the middle depth (76 cm) of box 6 and wagon 2 with the ambient relative humidities for the 1995 (A) and 1996 (B) storage seasons.

enced by ambient temperature and relative humidity.

Shelling outturns were statistically analyzed in 1995 to assess the simulated damage of handling into and out of the warehouse. Running peanuts through an elevator did not significantly increase the LSK. Previous warehouse studies showed an increase of 3% in LSK due to damage during loading and unloading from the warehouse. It was concluded that the simulated handling was not severe enough to represent warehouse handling. Before and after storage, shelling outturns of peanuts in 1996 showed a 2.1% decrease in the net value. The net value decrease was similar to the net value decrease due to shrinkage in warehouse storage (Butts and Smith, 1995). No differences were evident between the wagons and boxes for 1995 and 1996.

The cost/benefit of implementing a box handling/storage system was compared to the conventional wagon handling system for an on-farm and a peanut buying point scenario. The economic analysis was based on the following assumptions. The conventional 6.4-m peanut wagon had a 7-Mg capacity, could be used five times per year, and had no salvage value at the end of 7 yr. Each conventional wagon cost $3896. The box handling system consisted of 10-Mg boxes costing $2900 each and a truck/carrier system costing $12,000. Boxes and carrier were assumed to have a useful life of 10 yr. A forklift also is needed for moving and stacking boxes. Both systems had a 5-yr payoff at 10% interest.

For a typical farm producing 450 Mg of peanuts, a total of 45 boxes would be required with a total capital cost of $131,500 (Table 2). The total cost for the carrier and forklift are $12,000 and $5000, respectively. The annual fixed cost per ton of owning/leasing the box system is $52.05/yr/Mg. Similarly, the grower would have to purchase a total of 13 wagons to handle and transport 450 Mg of peanuts. The total capital cost is $50,654. The equivalent annual fixed cost per Mg is $19.98. Benefits associated with the box handling system includes an assumed reduction in the shrinkage of 2% and a reduction in LSK of 3% (Blankenship and Lamb, 1996). The reduced shrinkage and LSK equates to approximately $6740/yr and $8010/yr, respectively. The equivalent benefit per ton is $14.85 and $17.66 per Mg. Subtracting the $32.51 benefit from the annual cost of the box system, reduces the annual cost of the box system to $19.54 compared to $19.98 for the conventional wagon system.

Table 2. Economic analysis[a] data for box system compared to wagon handling system.

Item	On-farm costs (450 Mg)		Buying point costs (3600 Mg)	
	$	$/yr/Mg	$	$/yr/Mg
Box system				
Box 10 Mg	131,500	36.31	1,052,000	36.31
Carrier	12,000	4.72	72,000	3.55
Forklift	5,000	11.02	50,000	2.47
Drying wagon system				
Drying wagon 6.4 m	50,654	19.98	201,400	9.93
Benefits to box system				
Shrinkage reduction (2%)	6,740	14.85	53,920	14.86
LSK reduction (3%)	8,010	17.66	64,080	17.66
Costs				
Box system		19.54		9.80
Drying wagon system		19.98		9.93
Gain for box system		0.44		0.13

[a]Parameters used in the economic analysis are: 10% interest rate, 5-yr payoff each system, 10-yr useful life container system, 7-yr useful life wagon (five turn-arounds/yr) system, depreciation allowance. Shrinkage calculated at $0.742/kg and LSK at $0.558/kg.

A typical buying point handling 3600 Mg per year would require approximately 103 peanut wagons at a total cost of $201,400. The annual fixed cost for the peanut wagons would be $9.93/Mg. The buying point would require 360 boxes at a total cost of $1.05 million, six carriers at a cost of $72,000, and forklifts costing $50,000. The total annual fixed cost for the box system is $42.33/Mg. Reduced shrinkage and LSK would again result in an annual benefit of $32.51/Mg. The net annual cost of the box system is $9.80/Mg compared to the $9.93/Mg for the wagons.

A buying point also could realize some savings in the type of storage building necessary. A simple shed with minimal structural components could be used in lieu of the traditional peanut warehouse. The conventional warehouse must have structural integrity to support the sidewall loads of peanuts piled 7 m as well as the extensive structure for the overhead conveyor for loading the warehouse.

Significant differences exist in the capital investment between the box handling system and wagon curing/transportation system. If the benefits of reduced shrinkage and LSK accrue to the to the investor of the system, the annual cost/Mg of each system are comparable.

Conclusions

The wagons and boxes used in this study demonstrate peanuts can be safely stored in either wagons or boxes. The moisture content of the peanut kernels decreased to 7.5% more rapidly in 1995 than in 1996. The maximum and minimum temperatures within the top 15 cm of the container lagged the ambient temperature 6.4 and 4.3 hr, respectively. Average daily temperature in the wagons and boxes followed the ambient temperature. At the start of storage, the heat in the peanut mass following curing or generated due to a wide variation in moisture content required about 20 d to dissipate. Temperatures and relative humidities in the middle of the wagon and box responded to the outside surroundings much slower than the top level. Passing the peanuts through an elevator did not simulate the handling damage associated with warehouse loading and unloading. An economic analysis indicates handling peanuts with a box system concept favorably compared with the current handling practices and warehouse system.

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