Overspace Environment in Mechanically and Naturally Ventilated Peanut Storages

J. S. Smith*[1], J. I. Davidson, Jr.[1], T. H. Sanders[1], and R. J. Cole[1]

ABSTRACT

Two adjacent peanut storages, one mechanically ventilated and one naturally ventilated were instrumented to monitor overspace air temperatures midway between the peanuts and the roof at 2-hour intervals from mid-October through March. Overspace relative humidity measurements were recorded for each storage between the peanuts and the roof ridge.

Data were analyzed at bimonthly intervals for 11 periods. There were no differences between east and west side overspace temperatures or roof surface temperatures in the naturally ventilated storage during any given period. The mechanically ventilated storage had differences in overspace air and roof surface temperatures in some of the periods. Overspace air and roof surface temperatures were more uniform in the naturally ventilated storage, whereas the east side overspace air and roof surface temperatures were lower in the mechanically ventilated storage. Relative humidities were approximately the same throughout the test for both storages except for being higher in the naturally ventilated storage during the first and second periods and lower during the last period. The mechanically ventilated storage had less condensation potential during early storage than the naturally ventilated storage, but this trend reversed after the first 3 periods of storage.

Key Words: Peanuts, storage, warehouse, temperature, relative humidity, ventilation

The overspace environment in farmers stock peanut storages changes throughout the storage period. Quality of stored peanuts can be greatly affected by the air environment in this space. Moisture in warm air rising from the peanuts can condense on cool metal roofing or other surfaces that are at or below the dew point temperature of this air (1, 3). If this condensate then drips onto the peanuts, microclimates ideal for mold growth or other quality deterioration are created.

The objective of this study was to determine the effects of mechanical and natural ventilation on overspace environment throughout the normal storage period for farmers stock peanuts.

Methods and Materials

Two adjacent flat-type storages as described by Smith et al. (4) were used in this study. One was mechanically ventilated (Storage A) by 2 fans which provided an overspace air change rate of once every 3 minutes with air entering the north gable and exiting the south gable. The other storage (Storage B) was naturally ventilated by air entering louvers beneath the eaves and exiting through a continuous roof-ridge louver. The fans ran continuously and the louvers remained open throughout the storage season. A thermocouple in contact with the roof surface midway on each side 12 m from the north gable was used to determine roof temperatures. A thermocouple suspended midway between the roof and the peanut mass at the same location of each roof-temperature thermocouple was used to determine overspace temperatures. Outside temperature was sensed by a thermocouple located 1.5 m above ground in a radiation-shielded housing. All thermocouples were ANSI Type T.

A wide-range humidity sensor (Hygrodynamic's Hygrosensor[2]) was located in the overspace of each storage 1 m below the roof ridge 12 m from the north gable. Temperature and relative humidity measurements were recorded on strip chart recorders at 2-hour intervals from mid-October, 1979, through March, 1980 with temperature and relative humidity accuracies of ± 1 C and ± 5%, respectively. Daily means were determined for each sensor. These means were grouped into 11 bimonthly periods and analyzed using analysis of variance and general linear models procedures.

Storage A was completely filled, whereas Storage B was filled for about 2/3 of its length (approximately 3/4 full). The northern 1/3 of Storage B was originally overfilled to the extent that the eave vents were partially to completely covered. All eave vents were uncovered before the first of November.

A sheet metal trough was positioned under the first roof purlin from the ridge on the west side of the roof in each storage. These troughs began at the thermocouple and humidity sensor locations and extended south approximately 6 m. Condensation that formed between the ridge and the first purlin in quantities sufficient to run was collected in a 19-liter container in each storage. The area from which condensation was collected in each storage was approximately 7.4 m^2. Condensation measurements were made several times during each period through December, after which no further condensation sufficient to run to collection container occurred.

Results and Discussion

Mean overspace relative humidities were not different between the 2 storages for 8 of the 11 periods (Table 1). Relative humidities in Storage B were significantly greater during the first 2 periods and significantly less during the last period than those in Storage A. Fig. 1 shows the maximum, minimum, and mean overspace relative humidities by periods for both storages.

There were no significant differences in overspace

Table 1. Mean roof and overspace temperatures and overspace relative humidities in mechanically (A) and naturally (B) ventilated storages from mid-October through March 1979-80.

Period	West Roof °C		East Roof °C		West Overspace °C		East Overspace °C		Overspace % RH	
	A	B	A	B	A	B	A	B	A	B
Oct. 16-31	24.4	22.3	21.8	22.3	21.7	21.2	20.9	21.2	70.4*	79.8*
Nov. 1-15	18.5	17.4	14.6	17.1	15.7	16.3	14.3*	16.5*	60.5*	76.7*
16-30	13.6	11.6	9.1*	11.6*	11.1	11.3	9.3*	11.9*	68.5	73.2
Dec. 1-15	13.0	11.8	10.4	11.9	11.0	11.4	10.2*	11.7*	68.5	69.7
16-31	11.1	10.8	9.0*	10.6*	9.4	10.3	8.9*	10.2*	68.3	68.0
Jan. 1-15	10.7	10.1	9.0	10.0	9.3	9.4	8.7	9.4	72.4	71.0
16-31	13.1	13.2	11.4*	13.2*	11.7	12.2	11.2*	12.3*	72.4	68.5
Feb. 1-14	7.0	5.4	4.2	5.5	4.4	4.6	3.4*	4.8*	55.8	60.2
15-29	16.3	16.5	13.2*	16.8*	13.1	14.4	12.2*	14.7*	54.0	57.9
Mar. 1-15	14.3	14.6	11.8*	14.1*	11.7	12.8	10.6*	12.9*	64.7	61.2
16-31	18.0	18.6	16.0*	18.6*	15.4	16.4	15.0*	16.8*	55.2*	48.0*

* Denotes significance at $p = 0.05$ between A and B.

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[1] Agricultural Engineer, Mechanical Engineer, Plant Physiologist, and Research Microbiologist, USDA, ARS, National Peanut Research Laboratory, Dawson, GA 31742

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temperatures within storages throughout the test. Significant differences existed between the east and west side roof temperatures within storage A but not within Storage B. No significant differences existed between storages for the west side roof temperatures, however, there were significant differences in east side roof temperatures for all except the first period. Table 1 contains the mean roof and overspace temperatures and the mean relative humidities during storage. The east side temperatures in Storage A were lower than those in Storage B. Figs. 2 and 3 show the maximum, minimum, and mean temperatures for the east side and west side roofs while Figs. 4 and 5 show the corresponding overspace temperatures. The maximum, minimum and mean outside air temperatures are shown in Fig. 6. (Minimum temperatures in Storage A were not available from mid-November through January when temperatures dropped below 0 C because of recorder limitations below 0 C. Outside minimum temperatures were used in computing the means for Storage A during this time when temperature was below 0 C.)

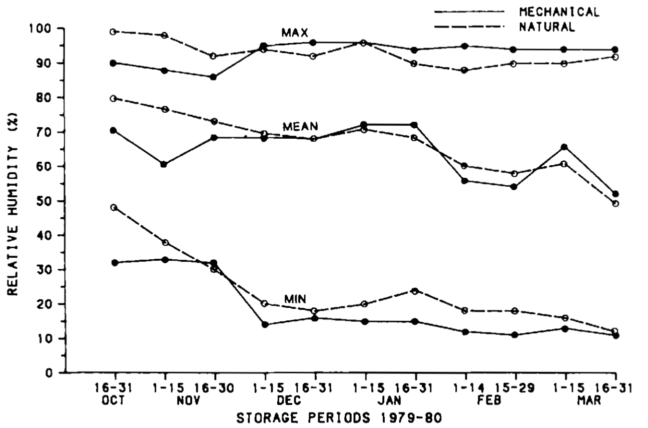

Fig. 1. Maximum, minimum, and mean overspace relative humidities during storage in two peanut storages, one with mechanical and one with natural ventilation.

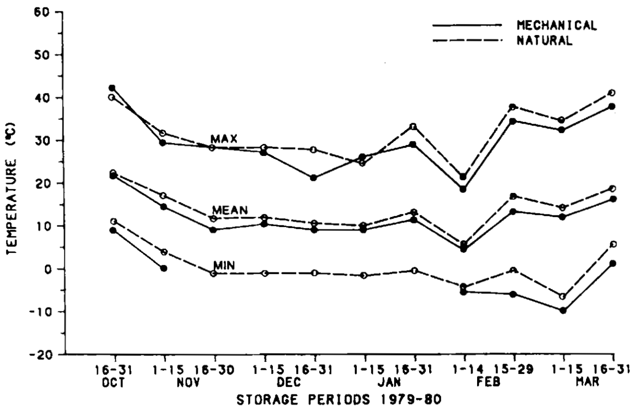

Fig. 2. Maximum, minimum, and mean east side roof temperatures during storage in two peanut storages, one with mechanical and one with natural ventilation.

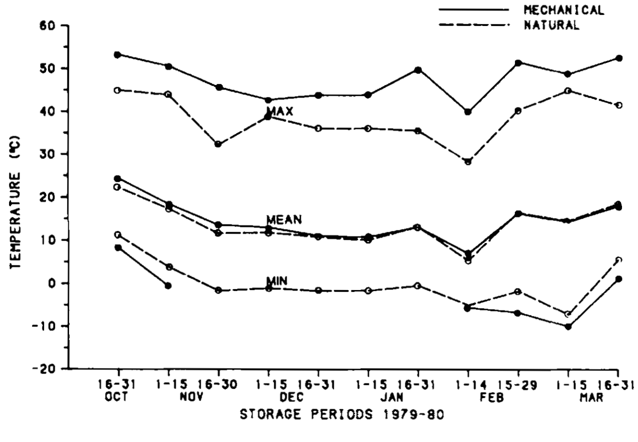

Fig. 3. Maximum, minimum, and mean west side roof temperatures during storage in two peanut storages, one with mechanical and one with natural ventilation.

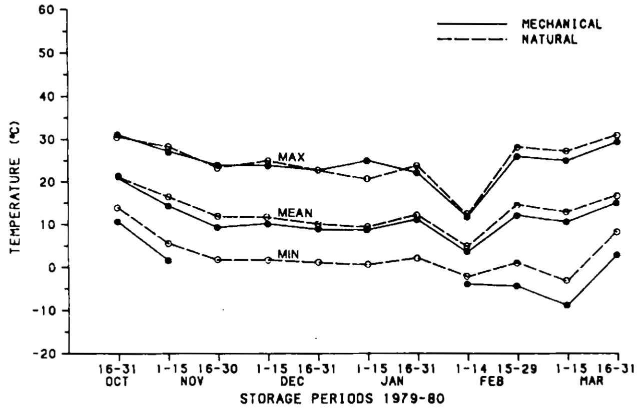

Fig. 4. Maximum, minimum, and mean east side overspace air temperatures during storage in two peanut storages, one with mechanical and one with natural ventilation.

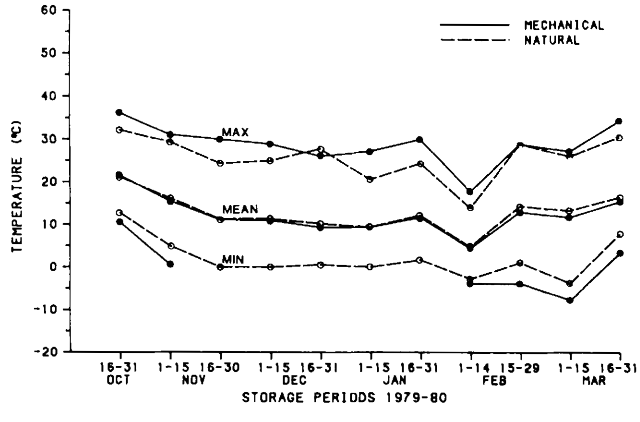

Fig. 5. Maximum, minimum, and mean west side overspace air temperatures during storage in two peanut storages, one with mechanical and one with natural ventilation.

The number of hours and days of condensation potential with the amounts of condensation collected during the first 5 periods of storage are given in Table 2. Condensation potential was determined from a conventional psychrometric chart using the overspace temperature and relative humidity to determine the corresponding dew point temperature. When the roof surface temperature was at or below the dew point temperature, the required conditions for condensation to occur existed.

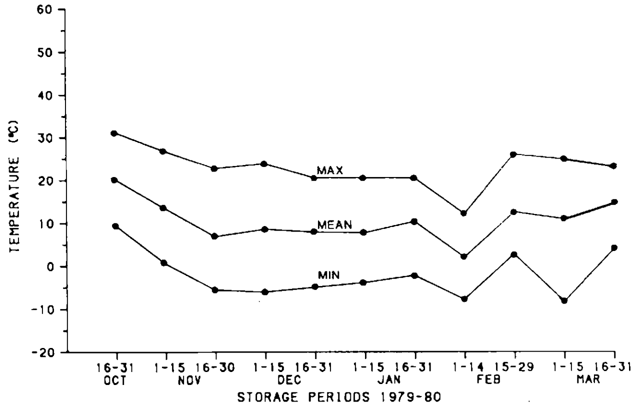

Fig. 6. Maximum, minimum and mean outside air temperatures during peanut storage.

Table 2. Hours and days of condensation potential with amount of condensation collected in mechanically (A) and naturally (B) ventilated storages from mid-October through December 1979.

Period	Storage A			Storage B		
	Condensation potential		Condensation collected	Condensation potential		Condensation collected
	Hours	Days	ml	Hours	Days	ml
Oct. 16-31	1[a]	1[a]	100	34	8	1966[b]
Nov. 1-15	13	3	952[c]	51	13	1250[c]
16-30	16	4	282[d]	19	5	70
Dec. 1-15	23	6	312[e]	58	7	96
16-31	15	8	6	11	5	0

[a] Condensation potential was not known for 4 days during this period when 100 ml of condensation was collected.

[b] Eave inlets were partially to completely covered during this period.

[c] Air inlets and outlets were sealed for 5 days during storage fumigation.

[d] Belt was broken on 1 fan for 2 days.

[e] Fan removed for 1 night to replace bearing.

Storage B had a mean relative humidity of almost 80% during period 1 (Oct. 16-31) compared to about 70% for Storage A (Fig. 1). During this same period 1966 ml of condensation were collected in Storage B while only 100 ml were collected in Storage A. Restricting the eave vents with peanuts in Storage B may have contributed to this. Condensation amounts were 952 and 1250 mL for A and B, respectively, for period 2 (Nov. 1-15). A total of 282 mL of condensation for period 3 (Nov. 16-30) was collected in Storage A from which 246 ml occurred during a night when only 1 fan was operating. Storage B had a total of 70 mL for the same period with none on the night that the fan was off in Storage A. These data illustrate the importance of adequate air movement through storages to minimize condensation.

Period 4 (Dec. 1-15) condensation amount in Storage A was 312 ml compared to 96 ml in Storage B. However, a fan in Storage A was not in operation the entire period. No condensation was evident after period 5 (Dec. 16-31) for which only 6 mL was collected from Storage A and none from Storage B.

Fig. 1 shows that the average relative humidity in Storage B was about 10% higher than that in Storage A at the beginning of storage but decreased almost linearly until period 4 (Dec. 1-15). No further condensation was evident in Storage B during storage and relative humidity stayed within the relatively safe storage range, 55-80% (3). The partial filling of Storage B may account for the higher humidities during the early periods of storage since air change rates were not enough to remove the excess moisture fast enough to prevent condensation.

The mean overspace temperature throughout storage was 11.6 and 12.7 C for Storages A and B, respectively. There was no significant difference within a given storage between east and west overspace temperatures; however, there was a significant difference between storages for the east overspace temperatures with Storage A being 1.6 C cooler.

A more uniform overspace temperature was maintained in Storage B than in Storage A (Figs. 4 and 5). Better air mixing was obtained in Storage B since the air entered the overspace through the louvers beneath the eaves and exited along the continuous ridge louver. The airflow was controlled by the temperature difference between the ambient air and the overspace air. Longer air paths moving horizontally across the overspace tend to produce stratified air flow patterns in Storage A. Obstructions such as purlins, girts and non-uniformity in the peanut pile surface affect the air flow pattern in Storage A, while cracks between the overlapping sheets of metal forming the roof produce short circuiting of air currents.

Data show that Storage A removed the moisture better during early storage than Storage B (Fig. 1). There was a considerable difference in the mean overspace relative humidities between storages during this time, with Storage A being much less. The forced airflow when ambient and overspace air temperatures differ only slightly lowers the moisture content of the overspace air in Storage A much more than the natural airflow in Storage B. There is little air flow in Storage B when the temperature difference between ambient and overspace air is small.

The west roof of Storage A had much higher maximum temperatures than the west roof of Storage B throughout storage. Based on the solar altitude and azimuth for the storages, this should only be true during midwinter (2). The higher maximum temperatures on the west roof of Storage A can be attributed to less air flow beneath the roof surface than in Storage B. The corresponding roof in Storage B would theoretically produce the greatest airflow during the time when the overspace temperature increase above ambient air temperature was maximum because of the "chimney effect" and natural convection currents. Warm air would be rising and replaced by cooler air, thus cooling the roof surface. This "chimney effect" was cancelled in Storage A since the fans tend to move the air laterally across the overspace.

Conclusions

The overspace temperatures in naturally ventilated storage (B) were more uniform but slightly greater than those in mechanically ventilated storage (A). The constant volume air flow in the mechanically ventilated storage (A) produced a lower mean overspace temperature than the variable air flow in the naturally ventilated storage (B). Relative humidity changes were lower in the naturally ventilated storage (B) than in the mechanically ventilated storage (A). Condensation potential was greater in the naturally ventilated storage (B) during early storage when humidities were high and inside-outside temperatures differed only slightly. During such periods air changes in the naturally ventilated storage (B) were minimal because the small temperature differences create little force for convention currents to form and produce the air changes needed to prevent condensation. Later in the season when differentials between inside-outside temperatures were greater, the mechanically ventilated storage (A) had an increase in condensation potential.

Results show the importance of properly filling naturally ventilated storages to avoid blocking air vents. Daily inspection of fans and related equipment in mechanically ventilated storages is necessary to insure proper operation. Failure to follow these filling and inspection procedures can create overspace environments that are conducive to mold growth or other quality deterioration. The naturally ventilated overspace offers a simple ventilating system while much of the time providing a satisfactory overspace environment. The mechanically ventilated overspace offers versatility in control and lower mean overspace temperatures but with a greater risk to quality loss should mechanical failures or problems occur. Improvements in existing overspace ventilating systems and/or development of better systems are needed to prevent quality losses during storage of farmers stock peanuts.

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