MOISTURE CHANGES IN DRY AND TOUGH WHEAT IN UNVENTILATED STORAGE SUBJECTED TO A COOLING-WARMING CYCLE

D. B. Ampratwum
Department of Agricultural Engineering
University of Alberta
Edmonton, Alberta

INTRODUCTION

Moisture plays an important role in the safe storage of grain. If the moisture content is maintained at a sufficiently low level, grain can be stored for many years with little deterioration. Low moisture levels limit development of harmful organisms, namely fungi, bacteria, mites and insects, that attack stored grain.

Changes in moisture content in stored grain may result from entrance of rain or snow, absorption of moisture from the air, redistribution or translocation of moisture due to changes in grain temperature or from heavy insect infestation.

Rain from a roof leak and snow blown through ventilators may enter bulk stored dry grain and cause damp grain pockets.

Grain will absorb or give up moisture until its moisture content is in equilibrium with the relative humidity of the surrounding atmosphere (7). Moisture is absorbed from the air if the equilibrium moisture content of the grain is below that of the atmosphere; drying occurs if the reverse is true.

When grain is placed in storage bins, redistribution of moisture occurs. This phenomenon, called moisture migration, has been observed by Carter and Farrar (5). The air in the storage space is in constant motion as a result of diffusion and/or convection. When air from a warm region in the grain reaches a cooler region, it must give up some of its moisture to the grain if the equilibrium condition is to be maintained. This interchange of moisture usually takes place entirely in the vapour phase, but, in extreme instances, warm air reaching a cold region in the storage space may be cooled below its dew point, with condensation occurring on the cold surface of the grain or walls of the bin.

Thus moisture is transferred from warmer to cooler regions of the stored grain. Anderson, et al (3), have reported that temperature differentials cause the movement of moisture in stored grain. They carried out a laboratory experiment which suggested that the chief cause of local increases in moisture content of dry wheat stored in country elevator annexes in Western Canada is a temperature differential established during winter. A temperature difference of 95°F, across 6 ft. of grain having an initial moisture content of 14.62%, caused the moisture content at a cold end (32°F) to rise to over 20% in 316 days.

Moisture accumulation is accelerated by insect infestation since the insects migrate to, and remain active in, the warmer portions of stored grain.

Moisture redistribution is considered to be a slow process with equilibrium conditions never established for any practical length of time (3). However, spoilage as a result of excessive moisture accumulation may occur in parts of stored grain even though none of the grain initially contained sufficient moisture to promote spoilage. Whether moisture redistribution takes place to the same extent in grain stored at different initial moisture contents under the influence of the same environment does not appear to have been investigated. Thus, the objective of the study reported here was to examine the moisture changes in bulk stored grain of two different moisture contents.

PROCEDURE

Air-oven method moisture determinations were made at the beginning and end of a cooling and warming cycle, on samples from dry and tough Manitou wheat, the amount of each grade being 82 bushels. The tough wheat was obtained by moistening dry wheat. This was achieved by spraying water over the dry grain while it was turned continuously.

Initial moisture determinations were made on 40 random samples from the bulk of dry and tough wheat, 20 from each grade. The samples were taken at random from bags of dry and tough wheat, using random number tables.

Four circular steel bins, each 4 ft. in diameter and 5 ft. high were loaded with wheat. Each bin contained 41 bushels of wheat to a height of 4 ft. Two bins contained dry wheat and two tough wheat. The four bins were subjected to 28 consecutive days of cooling in a cold chamber followed immediately by 35 consecutive days of warming in a warm enclosure (1). In the cooling condition, the environmental temperature dropped from 70°F to -20°F within 4 days with -20°F maintained thereafter with ±1° variation. Similarly, the temperature in the warm enclosure was increased from -20°F to 70°F in 4 days and held at this temperature, the maximum temperature fluctuation over any one 24 hour period being from 60°F to 70°F.

After the cooling and warming cycle, moisture content determinations were made on samples from the bins. Twenty-four samples from points predetermined by thermocouple positioning were collected from each bin. The sampling points are shown in Figure 1. To collect the samples, the grain was removed in layers by vacuum to ensure minimum disturbance and mixing in the bin. At the level of the thermocouple positions, the kernels in the neighborhood of each thermocouple were removed carefully with a metal scoop.

The weight of each sample taken was 100 grams. The whole kernel, air-oven method (8) was used in the...
moisture content determinations. The loss in weight was recorded as the percentage moisture content (wet basis).

ANALYSIS AND RESULTS

The factors considered in the experiment as influencing the moisture content of the grain were external temperature cycle, time, height from the base of the bin, radial distance from the centre of the bin and grade of the grain. An analysis of variance for these factors and their interactions was made using a program (6) of the University of Alberta Computing Centre.

The moisture means for days, radial spacing, layer and grade are given in Table I. The result of the analysis of variance is given in Table II.

Two main effects showed significant differences. The main effect due to layer was significant at 10% level of significance and that due to grade was significant at 1% level of significance. The significance of these main effects indicated that the variation of moisture content between the two layers is statistically significant at 10% and the variation of moisture content between the dry and tough wheat is statistically significant at 1%.

The only interactions found to be significant were Day x Layer interaction and Day x Grade interaction. Day x Layer was significant at 10% significance level and Day x Grade was significant at 1%. The interaction of day and layer (DL) and that of day and grade (DG) may be observed in Figure 2. The interactions are due to a differential response depending upon the combination of the factors. In both interactions there was a difference of direction of response. The interactions indicated that the factors were not independent of each other.

DISCUSSION OF RESULTS

The subjection of the dry and tough wheat to the cooling-warming cycle resulted in moisture movement in both grades of grain. The moisture variation between the two grades and that due to interaction of time and grade were found to be highly significant. These indicate that the difference between the moisture changes in the dry and tough wheat, for the moisture levels considered, under the influence of the same temperature cycle, was highly significant.

Barre and Sammet (4) have stated that moisture accumulations most often occur in the upper layer of grain. The significance which existed for the main effect due to layer and for the Day x Layer interaction supports this statement. The upper layer gained as much moisture as was lost by the lower layer (Table I and Figure 2) indicating moisture migration from the lower to the upper layer.

Hall (7) has reported that with warm grain in a bin with colder surrounding air, moisture accumulation is at the top of the grain and with cold grain in a bin with warmer surrounding air, moisture accumulation is at the bottom of the grain. In this experiment, the storage began as warm grain with cold environment, continued as cold grain with a warm environment and ended as grain with a central temperature higher than that of the environment. Thus, though

the final moisture tests indicated moisture accumulation at the top layer of the grain, there could also be a smaller accumulation at the bottom contributing to the effect of layer being significant at the 10% level. The lack of significance of the main effect due to radial spacing indicated a lack of horizontal moisture movement. The trend of vertical moisture movement

| Figure 1. Vertical and cross-sections of bin showing sampling points. Sampling points 1 to 12 are in upper layer. Sampling points 13 to 24 are in lower layer. |

<table>
<thead>
<tr>
<th>TABLE I: MOISTURE CONTENT MEANS IN PERCENT (WET BASIS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Means of days</td>
</tr>
<tr>
<td>First</td>
</tr>
<tr>
<td>13.91</td>
</tr>
<tr>
<td>Means of radial spacing</td>
</tr>
<tr>
<td>20 inches</td>
</tr>
<tr>
<td>13.93</td>
</tr>
<tr>
<td>Means of layer</td>
</tr>
<tr>
<td>Upper</td>
</tr>
<tr>
<td>14.10</td>
</tr>
<tr>
<td>Means of grade</td>
</tr>
<tr>
<td>Dry</td>
</tr>
<tr>
<td>11.21</td>
</tr>
<tr>
<td>Grand Means</td>
</tr>
<tr>
<td>13.93</td>
</tr>
</tbody>
</table>

CANADIAN AGRICULTURAL ENGINEERING, VOL. 12, No. 1, MAY 1970

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movement may, in part, be due to the fact that the tops of the bins were open to the environment.

The lack of significance due to day indicated that moisture redistribution is a slow process as pointed out by Anderson, et al. (3). This fact and the difference in the rate of moisture redistribution between the two grades may account, in part at least, for the increase and decrease respectively, as suggested in Figure 2, in the moisture contents of the tough and dry grain. Further contributing factors in this regard may include the levels from which the samples were taken and the increased fungal activity noted (2) in the tough grain over the period of the experiment.

### CONCLUSIONS

The conclusions are:

1. Moisture redistribution occurs in stored bulk grain subjected to a cooling-warming cycle. The moisture migration tends to be towards the upper layers, where the top surface of the grain is open to the environment. The main effect due to layer was found to be significant at 10% significance level.

2. Moisture variation among the radial spacings, and therefore the moisture variation in the horizontal direction, was not significant.

3. Under the influence of the same temperature cycle, moisture redistribution in grain stored at different moisture contents did not take place at the same rate. The rate was higher in the tough grain than in dry, the difference being highly significant.

### ACKNOWLEDGEMENTS

The authors acknowledge the suggestions and assistance of Dr. R. T. Hardin, Department of Animal Science, University of Alberta in preparing this paper. Acknowledgement is made to the Alberta Agricultural Research Trust for financial support.

### REFERENCES


