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Moisture Variability during Drying, Mixing, and Storage for a Feed Mill Wet Bin

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Abstract - As the world's population continues to grow, the demand for grain continues to increase. To keep up with this demand, proper drying and storage of grain is critical. Increasing the efficiency of these systems has been investigated, but there has been very little focus on the phenomena that occur inside a wet bin. This research investigated what effect a hopper bottom wet bin has on the moisture content of corn as it leaves the wet bin. By limiting this research to just a small scale drying setup with only three loads being held in a hopper bottom wet bin, such a profile was created for the 1/16th scale experimental test setup. To determine the effect of mixing of corns on moisture contents as it exits the wet bin, dye test was conducted. The results of showed that the mixing of the each load directly affect the moisture content in the unload increments. The moisture content profile is divided into three regions. Region I, the unload increments 1-3 are primarily load 1 only; Region II, the unload increments 4-6 are primarily mixing of only load 1 & 2; Region III, the unload increments 7-13 are primarily mixing of only load 2 & 3.

Keywords**:** Moisture Content, Drying Corn, Hopper, Wet Bin, Dye Test.

1. Introduction

Producing animal feed is a year-round industry, but harvesting the grain that is required to produce animal feed is not. Depending on the weather in any particular area, the harvest season for some grains can be as short as a few weeks or as long as several months. So grain is often stored for several months before it's needed. Harvest season for some farms is also dependent on the availability of equipment or whether or not the field needs to be used for additional crops that year. These limitations cause crops to be harvested too early or too late. Harvesting crops when they are not at their driest can lead to the moisture content being as high as 20 to 30 percent moisture [1]. For the long-term storage, some grains need to be dried to as low as 9 percent moisture (depending on the grain and climate of that part of the world). Drying the grain to the desired moisture content can be a significant cost for many feed mills.

Farmers only have a few options to dry their grain after harvest. When feed mills have their own drying systems, the grain can be sold directly to the feed mills. If not, farmers can sell to grain elevators. Grain elevators dry, store, and re-sell the grain. Both feed mills and grain elevators deduct the cost of drying from the farmer's profits. If the farm is equipped with its own dryer, it can dry and store the grain themselves. Regardless of the setup the process is similar.

The purpose of this research is to understand the phenomena that effect the moisture content of grain as it leaves a hopper bottom wet bin and enters a grain drier. There has been very little research done on these phenomena [2-4]. Research into the grain drying and storage process has focused primarily on the stresses in grain bins, technology advances in in-line grain dryer sensors, or issues that occur during grain storage. With a better understanding of the moisture content of grain as it enters a grain dryer, there is a potential to have a significant impact on the efficiency of the dryer. There is no current industry standard for parameter optimization of a grain dryer. Most feed mills, grain elevators, and farmers use past practice to establish parameter settings. If a profile could be created that could accurately predict the moisture content of grain as it leaves a wet bin, dryer parameter settings would no longer need to be determined through trial and error.

2. Experimental Approach

The test setup was scaled from equipment that could be found at a typical small scale feed mill that had an internal drying process. Figure 1 shows size specification of the equipment: a wet bin of sukup's 12 ft, diameter 45o hopper bottom medium duty bin with 1,492 bushel capacity; a gravity wagon of J&M's 250-7SB gravity wagon with 250 bushel capacity; a moisture tester of Dickey-John's Mini GAC moisture analyzer. The experimental test setup for this research was a 1/16th scale version of the Sukup's 12' diameter, 1,492 bushel capacity hopper bottom bin. Although typical grain bin construction is made of aluminum and steel, this test setup used translucent polycarbonate sheets. The plastic did not provide the rigidity that metal provides. To ensure that the plastic kept the proper dimensions, a stiffener was added to the seam and brackets were added for wall stiffening. Although using plastic did not give an exact replication of the full scale wet bin, it did allow for visual observations of the grain.

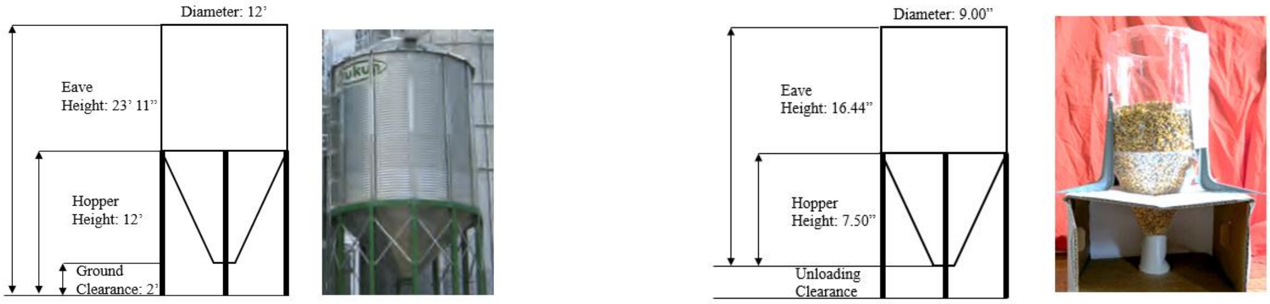

Fig. 1: (a) Medium Duty Hopper Bin Dimensions (b) Experimental Test Setup.

Each trial represented three grain loads. Each load size represented a 1/16th scale of J&M's 250-7SB gravity wagon. This gravity wagon's capacity is 250 bushel (8,810 liters). A graduated cylinder was used to accurately measure each 1/16th scale load to 2.15 liters. The grain used in all of the trials was shelled feed corn, which was harvested from the previous year's crop. All of the moisture content results were measured by Dickey-John's mini GAC moisture tester, which only had calibrations for full scale corn. So the corn itself was not scaled for this research.

This grain tester is a hand held unit that can quickly and accurately test the moisture content of a grain sample anywhere, including in the field. Dickey-John has over 450 load calibrations available for download. The mini GAC can be loaded with up to 20 calibrations at a time. For this research, their corn and corn high calibrations were used. This analyzer has an internal scale and temperature reader so the instrument can automatically compensate for sample temperature. It requires approximately 470 mL of grain for each test. The mini GAC can measure moisture content between 5 and 45 percent with an accuracy of 0.2 percent.

The grain used for this research was shelled feed corn. After harvest, it had been dried and stored. To get the desired moisture content for this research, it needed to be rehydrated. Each trial needed three moisture contents. The lowest moisture content used was the corn in its dried condition, approximately 12% m.c., to represent a very dry harvest. The medium moisture content used was approximately 18.5% m.c., to represent a typical harvest. To reach this, the corn needed to be hydrated in a bath of water for a minimum of 6 hours. The corn was then laid in a thin layer on absorbent material for at least 30 minutes to remove the surface water. The highest moisture content used was approximately 28% m.c., to represent an exceptionally wet harvest. To reach this, the corn needed to be hydrated in a bath of water for a minimum of 20 hours. It was then laid in a thin layer on absorbent material for at least 30 minutes to remove the surface water.

A low, medium, and high moisture content load was measured for each trial. The volume of each load was 1/16th scale of a 250 bushel capacity gravity wagon, 2.15 liters. The mini GAC moisture analyzer was used to measure the moisture content of each load before it was added to the wet bin. The wet bin was centrally filled from the top by gravity. As the corn was being poured, a visual inspection was done to ensure the corn was pilling as expected in the center of the bin. Figure 2. shows the loads being added to the wet bin. After the last load was added to the wet bin, the corn was allowed to sit for thirty minutes before being unloaded. This time represented the typical time required to get the grain dryer started at a small scale feed mill. The wet bin was then unloaded in increments. Each increment was only enough corn to fill the mini GAC moisture tester, approximately 470 ml. The moisture content of each unloaded sample was taken and recorded until the bin was empty. Figure 2 shows the wet bin being emptied.

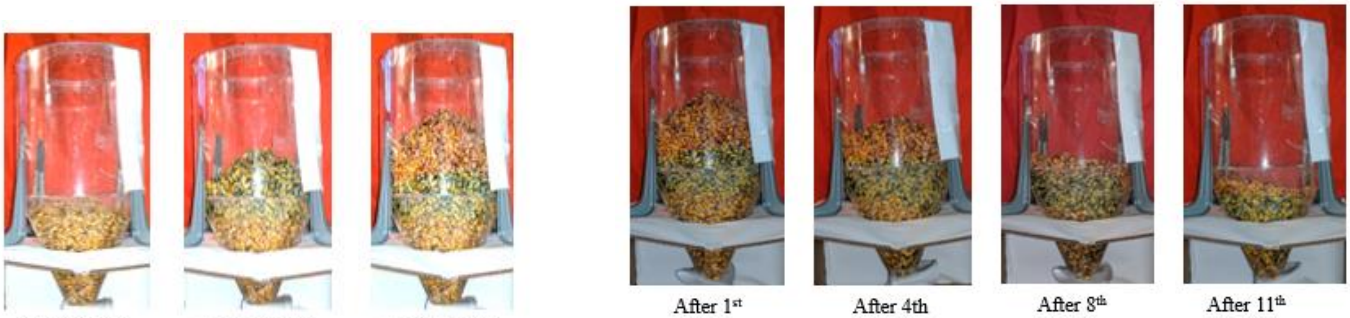
Load 1 Added
Load 2 Added
Load 3 Added
After 1st Unload
After 4th Unload
After 8th Unload
After 11th Unload

Fig. 2: Filling and unloading the test setup wet bin during the moisture content trials.

The same shelled feed corn that was used during the moisture content trials was dyed. The corn was allowed to soak in water that contained food coloring for 24 hours. The corn was then dried for 2 hours to remove any wet food coloring on the surface of the corn. The load sizes match the sizes used in the moisture content tests, 2.15 liters, which represented a 1/16th scale of a 250 bushel capacity gravity wagon. This test did not have any moisture content results, instead the percentage of each load was being investigated. So each load had been dyed a different color.

After the filling was complete, there was no need for the corn to sit thirty minutes because the effect of diffusion was not being factored into these trials. The unloading of the wet bin was gravity feed from the bottom of the bin. It was done incrementally to match the volume of the moisture content readings. Each increment was approximately 470 ml. After unloading was complete, each unload increment was separated by color and the number of corn kernels were counted. The percentage of each load that was found in each increment was recorded.

3. Results and Discussion

The filling order of the different moisture content loads is used for the experiment. First load for low moisture content of 12% m.c.; second load for medium moisture content of 18.5% m.c.; third load for high moisture content of 28% m.c.. The moisture content data collected during the unloading of each trial is shown in Figure 3. The figure shows the moisture content and order of each load during the filling process. The two simplest profiles that can be assumed for the moisture content of the grain as it leaves a hopper bottom wet bin, would be either a fully segregated profile or a fully homogenous profile. If the fully segregated profile was true, the results from the moisture content tests would all overlay the grey moisture content reference lines on the graph. If the fully homogenous profile was true, the results would all equal the average moisture content of 19.5 percent, regardless of the case being tested. It can easily be seen in the graph, that neither of these profiles are accurate. If either of these profiles were assumed at a feed mill, there would be both over dried and under dried corn entering the long-term storage grain bins.

To determine the effect of mixing of the corns on the moisture content as it exits the wet bin, dye test was conducted. The percentage of each load, or volume fraction, was determined for each of the unload increments. To determine if these results would create an accurate profile, the moisture content that was recorded for each load before it entered the wet bin was applied to the dye test results. The moisture content profile is divided into three regions in Figures 3 and 4. Region I, the unload increments 1-3 were primarily Load 1 only. As shown in Figure 3, the moisture content was not changed in the unload increments 1 – 3 which is 12% m.c. since there is no mixing between the Load 1of 12% m.c.and Load 2 of 18.5% m.c.. Region II, the unload increments 4-6 were primarily mixing of only Load 1 & 2. The mixing effect by Load 2 of 18.5 % m.c. increased by increasing the unload increments from 4 to 6. The increase of mixing effect from Load 2 increased the moisture content of the unload increments 4-6. Region III, the unload increments 7-13 were primarily mixing of only load 2 & 3. The contribution of Load 3 to Load 2 increases from unload increment of 7 to 11 and decreased slightly from 12-13. The moisture content in the unload increments 7-13 is directly affected by the mixing of Load 2 and 3.

If load mixing had been the only phenomenon to affect the moisture content of corn as it left a hopper bottom grain bin, the predicted results and actual results would be a match. The results are trending in similar directions. If a feed mill were to use this profile instead of assuming a fully homogenous or fully segregated profile, the efficiency of their grain drier may not be significantly impacted. There would still be some under dried and some over dried grain entering the long term storage grain bins.

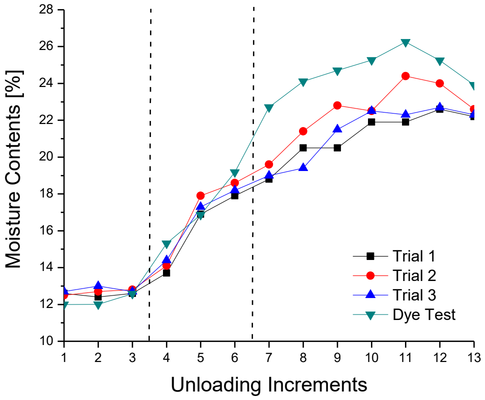

Fig. 3: Dye Test Results Compared to Moisture Content Test Results.

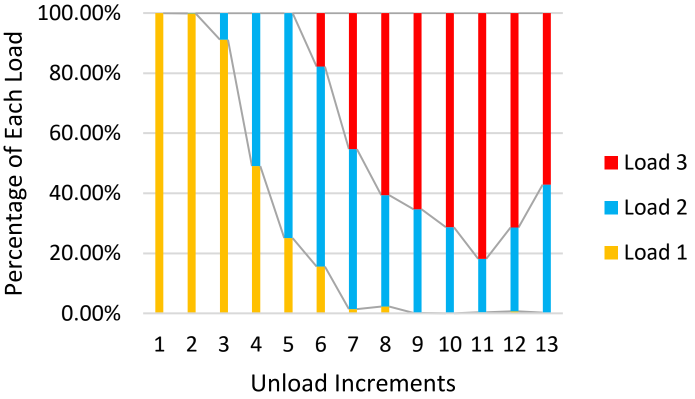

Fig. 4: Dye Test Results Compared to Moisture Content Test Results.

4. Conclusion

The results of this research show that a profile can be created that could predict the moisture content of grain as it leaves a hopper bottom wet bin and enters a grain dryer. By limiting this research to just a small scale drying setup with only three loads being held in a hopper bottom wet bin, such a profile was created for the 1/16th scale experimental test setup. This profile appears to be segregated into three distinct regions. Region I, the moisture content was not changed in the unload increments 1 – 3 which is 12% m.c. since there is no mixing between the Load 1of 12% m.c. and Load 2 of 18.5% m.c.. Region II, the increase of mixing effect from Load 2 of 18.5% m.c. to Load 1 increased the moisture content of the unload increments 4-6. Region III, the contribution of Load 3 of 28% m.c. to Load 2 increased from unload increment of 7 to 11 and slightly decreased from 12-13.

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