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The Influence of Harvest Rate and Drying Time on Grain Drying and Storage Facility Selection

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The selection of grain drying and storage facilities is dependent upon many factors with three of the more important being harvest rate, harvest volume and drying method. Other considerations include the type of hauling vehicle, the hauling distance, the type of handling equipment, labor and the economic feasibility of grain storage. To incorporate the foregoing considerations, the design computer simulation CHASE (Corn Handling and Storage Evaluator) was developed by Bridges et al. (1976b).

OBJECTIVES

Producers often make storage and drying equipment selections without considering the overall grain production system. CHASE provides the capability for a producer to see the effects of his decisions on system selection applied to his operations. Of particular interest to a producer would be the influence of harvest rate in the selection of a drying technique. With this in mind, the purpose of this study was to use the design computer simulation CHASE to accomplish the following objectives:

1. To determine the least cost drying method as a function of harvest rate by varying the harvest volume and the number of harvest days.
2. To determine the influence of hauling vehicle, handling technique and market option on the selection of the least cost drying method.
3. To determine the effect of drying time on the least cost drying facility.

PROGRAM DESCRIPTION AND INPUT

CHASE utilizes selected producer inputs and presents a ranked order with regard to cost for alternative methods of hauling, handling, drying, and storage of grain. CHASE, along with other programs dealing with the design and economics of grain storage and drying (Benock et al., 1977; Loewer et al., 1975, 1976a), is currently being used by the Cooperative Extension Service at the University of Kentucky.

The flow network described by CHASE contains a total of 60 combinations of hauling, handling, drying and storage (Fig. 1). Each combination is a feasible system. The annual cost for a system reflects only a percentage of the total fixed annual cost of tractors and trucks. This percentage was calculated from the design harvest rate for each system. An inherent assumption of the model is that there are sufficient hauling vehicles such that the combine never waits to unload during harvest. After all systems are designed, the program incorporates list prices to calculate an investment and annual cost for each system and ranks them accordingly. CHASE also presents the equipment and labor required by each feasible system.

Economic Concepts

Purchase costs were determined through cost arrays and equations using manufacturer's suggested list prices of representative companies (Table 1). Annual costs were calculated using straight-line depreciation, an estimated life and rate of repair, and constant interest, tax and insurance rates (Loewer et al., 1976b).

CHASE includes in the purchase cost of a particular system the cost of all vehicles required to sustain the harvesting operation. The annual cost for a system reflects only a percentage of the total fixed annual cost of tractors and trucks. This percentage was calculated as the number of harvest days divided by 365. As will be shown later, this factor does not influence the break point between drying techniques.

CHASE (Bridges et al., 1976c) is a deterministic model that allows the producer to see the consequences of his decisions. The model conducts a comparison of equipment systems relative to themselves without regard to potential economic return resulting from the sale of the grain. While it is recognized that the economic return to a system is of great importance, the model design criteria is that all sixty equipment systems will yield the same quality and quantity of grain. The effects of marketing and facility management upon economic return has been addressed in other studies including Loewer et al., 1978.
THE HECTARES OF CORN WERE MULTIPLIED BY A CONSTANT YIELD (A) COMMERCIALLY AVAILABLE DRYING FANS USUALLY DO NOT
OF 8.71 M/HA (100 BU/acre) TO OBTAIN HARVEST VOLUME
INCREMENTS. FOR THIS STUDY THE MINIMUM AND MAXIMUM
WERE VARIED:
(350), 161.87(400), 182.11(450) AND 202.34(500).
2 HARVEST DAYS: 1 THROUGH 30.
OTHER INPUT PARAMETERS PREVIOUSLY MENTIONED REMAINED
CONSTANT THROUGHOUT THE STUDY AND ARE LISTED IN TABLE 2.
THE HECTARES OF CORN WERE MULTIPLIED BY A CONSTANT
YIELD OF 8.71 M²/HA (100 BU/acre) TO OBTAIN HARVEST VOLUME
INCREMENTS. FOR THIS STUDY THE MINIMUM AND MAXIMUM
HARVEST RATES WERE 31.72 AND 352.4 M² (900 AND 10,000
BU) PER DAY, RESPECTIVELY. HARVEST RATES ABOVE AND BELOW
THOSE LIMITS WERE NOT CONSIDERED.
IN-BIN DRYING SYSTEMS (LAYER AND BATCH-IN-BIN) WERE
RESTRICTED TO ONE PER BIN WITH A MAXIMUM SIZE OF
14,913.8 W (20 HP). THERE WERE TWO REASONS FOR THIS:
(A) COMMERCIALLY AVAILABLE DRYING FANS USUALLY DO NOT
EXCEED THIS POWER RATING, AND (B) CHASE WAS DEVELOPED
MAINLY FOR KENTUCKY FARM SITUATIONS WHERE THREE-PHASE
POWER IS A RARITY.
Table 3 shows an example of the data output for this
study. Twenty-four such tables were developed (Bridges et al., 1976a), each representing the least cost drying method for a particular system combination of harvesting, handling technique, and market option.
Six types of hauling vehicles were considered: gravity wagons, auger wagons, manually unloaded wagons, manually unloaded trucks, and dump trucks.

**TABLE 1. PRICE REFERENCES USED IN CHASE**

<table>
<thead>
<tr>
<th>Item</th>
<th>Company</th>
<th>Effective date</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Bin structure</td>
<td>Circle Steel Corp.</td>
<td>August 31, 1974</td>
</tr>
<tr>
<td>2. Perforated floor*</td>
<td>Circle Steel Corp.</td>
<td>August 31, 1974</td>
</tr>
<tr>
<td>3. Unloading auger, 6 in. *</td>
<td>Cardinal</td>
<td>November 1, 1974</td>
</tr>
<tr>
<td>4. Electric motors</td>
<td>MFS</td>
<td>January 1, 1975</td>
</tr>
<tr>
<td>5. Aeration fans</td>
<td>MFS</td>
<td>February 15, 1975</td>
</tr>
<tr>
<td>6. Foundation ring</td>
<td>Circle Steel Corp.</td>
<td>August 31, 1974</td>
</tr>
<tr>
<td>7. Aeration sulphur</td>
<td>Circle Steel Corp.</td>
<td>August 31, 1974</td>
</tr>
<tr>
<td>9. Grain spreader</td>
<td>Circle Steel Corp.</td>
<td>August 31, 1974</td>
</tr>
<tr>
<td>10. Humidistat</td>
<td>Circle Steel Corp.</td>
<td>August 31, 1974</td>
</tr>
<tr>
<td>11. Thermostat</td>
<td>Circle Steel Corp.</td>
<td>August 31, 1974</td>
</tr>
<tr>
<td>14. Transport auger</td>
<td>Hutchison</td>
<td>January 1, 1975</td>
</tr>
<tr>
<td>15. Fans with heaters*</td>
<td>Farm Fans, Inc.</td>
<td>January 1, 1974</td>
</tr>
<tr>
<td>16. Portable batch dryers</td>
<td>Super B</td>
<td>February 1, 1975</td>
</tr>
<tr>
<td>17. Continuous flow dryers</td>
<td>Butler</td>
<td>June, 1975</td>
</tr>
<tr>
<td>18. Trucks</td>
<td>International</td>
<td>March, 1975</td>
</tr>
<tr>
<td>20. Combiner and combine heads</td>
<td>Official guide from Ky.</td>
<td>Fall, 1974</td>
</tr>
<tr>
<td>21. Construction cost</td>
<td>Southern States</td>
<td>November, 1974</td>
</tr>
</tbody>
</table>

*Includes accessory equipment.
†All prices were obtained at the February, 1975 Farm Machinery Show in Louisville, KY.
that there were significant differences in the break-point line. Generally, for Market Option 2 (on-the-farm handling technique but different market options found storage after drying), and a given number of harvest days available.

Due to discrete intervals in harvest volumes, no attempt was made to pinpoint the exact harvest rate at which the break-point between drying methods occurred. The break-point for systems containing Market Option 1 was generally found to be in a range of 132.1 to 151.5 m³ (3750 to 4300 bu) per day. The break-point for systems containing Market Option 2 was somewhat less, generally falling in a range of 116.3 to 133.9 m³ (3300 to 3800 bu) per day. As stated previously, Market Option 2 requires storage, therefore, requiring more moisture to be removed and hence increasing the required drying capacity.

For harvest rates above the minimum up to the break-point line, this study concluded that batch-in-bin drying was the least cost drying method of those considered regardless of system combination. Above the break-point line, up to the maximum harvest rate, continuous-flow drying became the least cost drying method of those considered. It should be noted that within the ranges mentioned above, the two drying techniques are competitive in both price and capacity.

### RESULTS

Selection of a particular drying method for a given system combination such as that shown in Table 3 was based on least annual cost. The first number in each cell represents the investment cost of the system containing the least cost drying method. Listed below the larger number is the annual cost for that particular system. The heavy line represents the drying method break-point or the place in the table where the least cost system changes drying technique. It should be noted that the only two drying techniques appearing were batch-in-bin and continuous-flow drying.

The 24 system combinations were arranged by market option and handling technique in groups of six representing the six types of hauling vehicles. It was noted that within a grouping of six the break-point between drying techniques was the same, indicating that type of hauling vehicle has little or no effect upon the selection of drying method at a fixed distance.

A comparison of system combinations with like market options but different handling techniques also showed no difference in the break-point line. This indicates that the type of handling technique, portable auger or bucket elevator, has no effect upon the selection of the least-cost drying method as long as sufficient handling capacity is available.

Contrasting system combinations with the same handling technique but different market options found that there were significant differences in the break-point line. Generally, for Market Option 2 (on-the-farm storage after drying), and a given number of harvest days the break-point appears sooner across the range of harvest volumes than for Market Option 1. A contributing factor to this is the additional moisture that must be removed when the grain is stored as opposed to selling it immediately after drying (Table 2).

### Facility Cost and Drying Time

In crossing the break-point line from batch-in-bin drying to continuous-flow drying (Table 3), investment and annual cost significantly increase for a given number of harvest days. This indicates that the break-point line is due to the power limitation on the in-bin drying system fans.

One factor that contributed to this cost increase was that the portable drying time was limited to 12 h/day while that of batch-in-bin was 17 h/day. In comparison, both drying times are typical values, but the continuous-flow system has more flexibility with regard to increasing the total quantity of grain that may be dried in 1 day.

Further inspection of Table 3 shows some interesting system costs. An example of these occur for harvest volumes of 528.6 and 1057.2 m³ (15,000 and 30,000 bu) and 4 harvest days. Both the investment and annual cost for the continuous-flow drying system are more than double that of the batch-in-bin drying system. This indicates for the range of parameters of the simulation (Table 2), that two batch-in-bin drying systems for a 528.6 m³ (15,000 bu) harvest volume would be less expensive than one continuous flow system for 1057.2 m³ (30,000 bu). This cost difference is a function of drying time.

Table 4 shows a comparison of the two drying methods at different harvest rates and drying times. It can be seen that as the continuous-flow drying time increased from 12 to 24 h both the investment and annual cost of the respective systems decreased and that the continuous-flow system became competitive in price with the batch-in-bin system at 19 h.

While the study rendered the batch-in-bin system at 1057.2 m³ (30,000 bu) infeasible (larger than maximum fan size), it can be seen that the continuous-flow system at 19 h was cheaper both in investment cost and annual cost. The data in Table 4 indicate that had the study been conducted with a portable drying time of 19 h, as opposed to 12 h, and no fan limitation on the

### Table 4. Cost Comparison of Batch in Bin and Continuous Flow Drying*

<table>
<thead>
<tr>
<th>Harvest days</th>
<th>Harvest volume (bu)</th>
<th>Drying method</th>
<th>Drying time h/day</th>
<th>Investment cost, $</th>
<th>Annual cost, $</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>528.6 (15000)</td>
<td>B-1 B, CF</td>
<td>17</td>
<td>33120</td>
<td>4847</td>
</tr>
<tr>
<td>4</td>
<td>528.6 (15000)</td>
<td>CF, CF</td>
<td>12</td>
<td>37046</td>
<td>5183</td>
</tr>
<tr>
<td>4</td>
<td>528.6 (15000)</td>
<td>CF</td>
<td>19</td>
<td>33289</td>
<td>5183</td>
</tr>
<tr>
<td>4</td>
<td>528.6 (15000)</td>
<td>CF</td>
<td>24</td>
<td>52375</td>
<td>5014</td>
</tr>
<tr>
<td>4</td>
<td>1057.2 (30000)</td>
<td>B-1 B, CF</td>
<td>17</td>
<td>66394</td>
<td>9253</td>
</tr>
<tr>
<td>4</td>
<td>1057.2 (30000)</td>
<td>CF</td>
<td>12</td>
<td>72501</td>
<td>10922</td>
</tr>
<tr>
<td>4</td>
<td>1057.2 (30000)</td>
<td>CF</td>
<td>19</td>
<td>60129</td>
<td>8007</td>
</tr>
<tr>
<td>4</td>
<td>1057.2 (30000)</td>
<td>CF</td>
<td>24</td>
<td>57830</td>
<td>7920</td>
</tr>
</tbody>
</table>

*Cost comparison is for the system combination including dumptrucks, transport auger and market option 1.

†Batch-in-bin drying technique.

‡Continuous flow drying technique.
in-bin drying systems, continuous-flow drying would appear in the tables as a least cost drying method and that the system cost increase across the break-point line would be more uniform. Table 4 also shows that for 19 h drying time the continuous-flow system for 1057.2 m$^3$ (30,000 bu) is no longer twice as expensive as the batch-in-bin system for 528.6 m$^3$ (15,000 bu).

**SUMMARY AND CONCLUSIONS**

The design computer simulation CHASE was used to determine comparative purchase and annual costs of selected systems. The design inputs of crop area and harvest days were varied over a range of values and the least cost drying method was determined. The system combinations were grouped by market option and handling technique with each group including all vehicle types specified by CHASE.

Over the range of input parameters it was found that:

1. Within market options, there was no influence upon the break-point line due to hauling vehicles and handling techniques.
2. For Market Option 1 (Selling immediately after drying), the break-point line was generally in the range of 132.1 to 151.5 m$^3$ (3750 to 4300 bu) per day.
3. For Market Option 2 (On-the-farm storage after drying), the break-point line was generally in the range of 116.3 to 133.9 m$^3$ (3300 to 3800 bu) per day.
4. For harvest rates below the break-point, batch-in-bin drying was the least cost drying method and for rates above the break-point continuous-flow drying became the least expensive method.
5. The amount of time assigned for portable drying is an important factor in system costs comparisons.

The results shown in this paper are an evaluation of drying methods for the particular set of input conditions listed in Table 2. While the model includes only those drying methods discussed, there may be other drying methods (batch-in-bin with multiple fans or continuous-flow drying using dryeration) that are more suitable to the producer's needs. There may also be other factors such as labor or convenience that influence his selection of a drying facility. This study is an attempt to show an application of the model CHASE where the producer might vary input parameters to determine economic break-points and the influence of drying time for his own set of farm conditions.

CHASE designs 60 different systems for each particular situation. List prices were incorporated to reflect as true an investment and annual cost as possible. However, the real value of these data lies in the relative comparison of costs rather than the actual costs themselves.

**References**

8. Loewer, O. J., Jr., T. C. Bridges, G. M. White and D. G. Overhults. 1978. The influence of harvesting strategies and economic constraints on the feasibility of farm grain drying and storage facilities. Presented at the Southeast-Southwest Region of ASAE, Feb. 5-8, Houston, TX.