INVESTIGATIONS OF SUNFLOWER DRYING

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Increased sunflower production in the Red River Valley during the past few years resulted in increased use of farm grain dryers. Some of the need for grain drying has resulted from harvesting sunflower seeds at moisture contents above safe storage levels. This practice has reduced losses from birds, head dropping, and shattering while harvesting. Also, late in the fall the seeds may never reach safe storage moisture levels in the field due to inadequate drying by sunlight.

Since many growers have little experience with sunflower production and practices, many questions have been presented concerning sunflower seed drying. A common problem occurring with sunflower drying is fires that originate within the drying equipment. Many fires have occurred while drying these seeds, but in many cases the resulting damage was small because the drying equipment was closely monitored and corrective action was immediately taken to eliminate the fire. In some cases, the drying equipment was not monitored and the damage was extensive.

In this study, attempts were made to determine some causes of fires and to suggest practices that will reduce fire occurrence while drying sunflower seeds. To get a better understanding of dryers and related fires, temperatures were monitored on two dryers installed on farms. Before discussing these tests, some of the possible causes of fires, based on previous investigations, are noted. Spontaneous heating and combustion was suggested as a possible cause of these fires. One purpose of monitoring temperatures was to determine the presence of spontaneous heating. The concept of spontaneous heating has been well documented and believed to be a result of a number of factors. Plant respiration or activity in the plant material with the presence of excess moisture causes some initial heat. Another source of heat with excess moisture are microorganisms. These two heat sources can raise the temperature up to 170°F, but above this level microorganisms can no longer exist. At this point,

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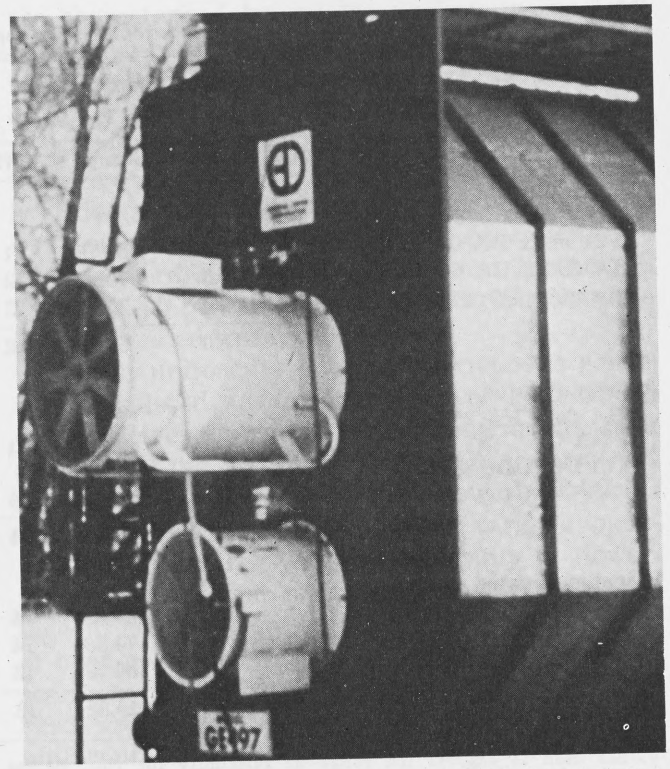

Fig. 1. The continuous flow dryer used in these studies.

chemical oxidation produces much of the heat, and excessive temperatures may exist in the biological product. Koegel and Bruhn reported temperatures as high as 1,500°F in alfalfa (1). Of course, these temperatures caused ignition.

In other studies of spontaneous heating with sunflower seeds, Salans et. al. indicated spontaneous heating does occur in sunflowers stored at 77° F and at a moisture content as low as 10.5 per cent (2). With moisture contents at 16.9 per cent, which is more representative of seeds entering grain dryers, the spontaneous heating occurred after two days of storage at 77°F. In the work with spontaneous heating of alfalfa, Koegel and Bruhn indicated a temperature rise with alfalfa after 10 hours when held at 200°F and under very humid conditions (1). Although the temperatures used in drying are much higher than the 77°F, presence of spontaneous heating in continuous flow dryers appears to be non-existent. But with non-circulating batch dryers and bin dryers, spontaneous heating may exist, although it may not be detrimental.

Another possible cause of dryer fires is from the open flame used to heat the air. Some material may enter the fan and burner resulting in ignition of the particles which come in contact with other material in the plenum chamber. Handling sunflower seeds produces dust or fuzz, and this material may be very combustible. In many commercial dryers, this dust and fuzz tends to accumulate in the plenum chamber. Therefore, when a particle enters the fan and burner and is ignited a fire may often result. Our tests show that this is the most common cause of dryer fires.

A characteristic of most commercial dryers on the market today is that they were designed for drying corn, which has a bushel weight of 56 pounds, about twice the sunflower seed bushel weight. When comparing the drying of these two crops, only about half as much moisture has to be removed from sunflower seeds to obtain the same per cent change in moisture content as in corn. For example, to reduce the moisture content from 20 to 15 per cent, approximately one gallon of water has to be removed from a bushel of corn. For sunflower seeds about one-half gallon is removed per bushel for the same per cent change in moisture content.

Since there is less moisture to be removed from the sunflower seeds, they dry more rapidly and the result in many cases is overdrying of the seeds. Overdried seeds are easily ignited when exposed to burning fuzz particles. On many continuous flow dryers the seed flow rate is variable. When drying sunflowers many dryer operators set the flow rate near maximum and many times overdrying may occur. Since most commercial dryers have a cooling section, moisture may be added to the seeds before leaving the dryer, and as a result the overdrying goes unnoticed. Overdrying the seeds may be a contributing factor to dryer fires.

Field Testing

The testing consisted principally of monitoring temperatures of dryers and observing the surrounding conditions. The temperatures were monitored on a bin dryer near Clifford, N. D., and a continuous flow dryer near Northwood, N. D. The work with these dryers will be discussed separately.

Bin Dryer

The procedure used in drying the sunflower seeds was to fill the bin to a depth of five feet and then force heated air through the perforated floor in the bin. A traveling stirring device consisted of a vertical conveyor screw suspended from the ceiling and moved through the sunflower seeds. This device brings warm dry seed from the bottom to the top to mix the wet and dry seeds.

The device for monitoring temperatures consisted of a number of thermocouples and a multipoint recorder. The thermocouple junctions were placed in the bin at one-foot incremental depths beginning at three inches above the floor. Other thermocouple junctions were placed to record temperature of ambient air and air leaving the burner.

During the first batch, the temperature of the air in the burner was 120°F. After two hours the temperature of the seeds three inches from the floor was 103°F while the temperature at the one-foot increment above this was near 60°F which was very near the ambient temperature. The drying zone had not reached the upper levels. As drying progressed, temperatures in the upper layers did increase. Since none of these temperatures appear out of line, spontaneous heating was believed to be non-existent. A similar pattern was noted on subsequent batches.

When drying was complete, the burner was turned off and air continued flowing, thus cooling the seeds. After the fan was stopped, the temperature began to rise which was caused by the heat at the center of the individual seeds. Although the surface of the seed was cooled, the inner portion of each seed was still warm, which resulted in the transfer of heat to the surface. At first the temperature rise was believed to be caused by spontaneous heating, but some time later the temperature reached a maximum and then decreased.

Continuous Flow Dryer

Construction of the continuous flow dryer is shown in Figure 1. Wet grain entered at the top of the dryer and moved down through the dryer, dividing on each side of the heating and cooling chamber. Grain on each side of the dryer moved down in a series of four columns. Dried grain was discharged at the bottom through a screw conveyor. Discharge rate of the screw conveyor was adjusted manually. Moisture content of the grains entering the dryer varied very extensively for the various tests conducted. Discharge moisture content was maintained near 10 per cent for the oil varieties and 12 per cent for confectionery varieties. In some cases, one pass through the dryer was insufficient to dry the sunflower seeds down to the prescribed level. In that case, the seeds were recirculated through the dryer.

Temperatures were again monitored through the use of thermocouples. These junctions were placed to sense temperature of the air leaving each of the eight columns of sunflower seeds at approximately six feet above the ground. Other temperatures monitored were the ambient air, the plenum chamber air, the air leaving column number two approximately eight feet above the ground, and the air leaving column number two by the cooling chamber. The columns were numbered as shown in Figure 2. For the tests concerning the continuous flow dryers, the plenum chamber temperature was set near 165°F, but the control system of the dryer

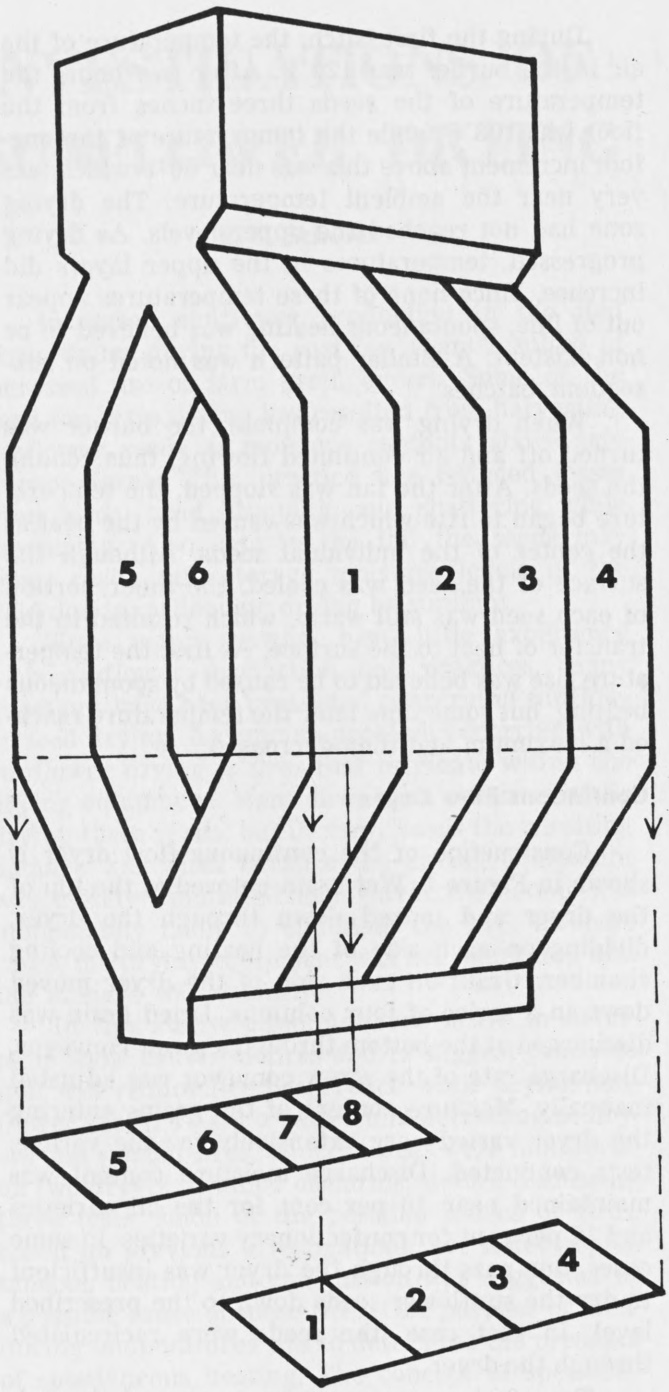

Fig. 2. Schematic of the continuous flow dryer and a cross-section view showing the numbering of the dryer columns.

allowed the temperature to fluctuate greatly. Due to the rapid cycling and the nature of the recording equipment, an accurate determination of the plenum chamber temperature variation was not made.

Temperatures were recorded on the dryer as the various lots were dried for this particular drying installation. The various lots of sunflower seeds that were dried are listed in Table 1 with the following information: date, per cent dockage, initial moisture content, final moisture content, temperature range of the air leaving the dryer, and sunflower seed variety. On two dates, fires occurred and they are noted in Table 1.

Table 1. List of the tests conducted.

Date	Per Cent Dockage	Moisture Content: Initial	Moisture Content: Final	Temp of air Leaving Variation	Variety
Nov. 9	12	15.0	9.5	70-105	Peredovik
Nov. 9	12	15.0	9.5	75-130	Peredovik
Nov. 10[1]	12	15-35	9.5	75-145	Peredovik
Nov. 12	3	14.0	12.0	70-95	Arrowhead
Nov. 15	3	17.0	12.0	70-85	Commander
Nov. 18	A Clean[3]	35.0		50-85	Peredovik
	B Clean		10.0	90-110	Peredovik
Nov. 18	12-15%	30.0	12.0	75-150	Arrowhead
Nov. 18	Clean	27.5	12.0	75-90	Commander
Nov. 20	5%	20.0	12.0	55-95	Commander
Nov. 20	Clean	20.0	12.0	80-105	Arrowhead
Nov. 22	Clean	14.0	12.0	70-85	Arrowhead
Nov. 22	Clean	20.0	12.0	75-90	Commander
Nov. 26[2]	Clean	20.0	12.0	70-100	Commander

[1]One fire was observed.
[2]Three fires were observed.
[3]The sunflower seeds that are noted as clean had a dockage of less than 3%. Also on November 18 the first lot was recirculated when A and B indicate the first and second pass respectively.

Study of this table highlights a few interesting points. The lots of seeds which have a high per cent dockage also have a large temperature variation for the air leaving, except for the first lot. Temperature of the air leaving the dryer was 130°F or higher for some columns, where the lots had a dockage of 12 per cent or more. These temperature variations were due to the uneven drying which took place in the dryer. High air temperature leaving the dryer indicated the material has been overdried. Overdrying is due to uneven flow of the sunflower seeds through the dryer. Some columns may have more trash than others, thus changing the flow characteristics of the materials in the columns. The temperature variation with time in some of the columns will be discussed later.

Looking at the first occurrence of a fire noted in Table 1, the sunflower seeds were very trashy. This first fire was observed in column 8 where white dense smoke was noted leaving the dryer about seven feet above the ground. The temperature of the air leaving this column was 84°F. Some of the other columns had temperatures much higher, up to 145°F. After noticing the fire, the burner and fan were turned off and the dryer was cleaned out. Very little sunflower fuzz had accumulated in the plenum chamber. The cause of this fire was not determined, but the presence of trash was believed to be a contributing factor. Drying was resumed for this lot without more fires.

On November 26, three fires were observed at different times. As noted in Table 1, the sunflower seeds were relatively clean and also the temperatures were 100°F or less. When the fire was observed, the fan and burner were turned off and the plenum was inspected. There were numerous accumulations of trash in the plenum chamber and several of these accumulations were burning. The locations of these small fires were in the center of the plenum chamber on the divider at columns 2 and 6, in the corner of the plenum chamber near column 5, in the corner near column 1 and in the cooling chamber near column 8. A fire in the cooling chamber could have started as a result of trash falling down from the plenum chamber. Sunflower trash or material in the plenum chamber would burn only when air was moving into the plenum chamber. When the fan was turned off, the flames went out because they needed a source of oxygen to burn. The dryer was cleaned of all sunflower seeds and trash.

Drying was continued, and after a short period of time another fire was seen. This fire seemed to be in the cooling chamber or the conveying system at the bottom of the dryer. The observed smoke was leaving column 5. Again the dryer was emptied and material cleaned out of the plenum and cooling chambers.

Drying was again resumed and a short time later another fire started. A large volume of smoke was observed leaving column five. The plenum chamber was again inspected to determine the location of the fire. Trash was burning in the lower corner of the plenum chamber near column 5. Also there was fire on the wall of column 5. Some sunflower material also was burning in the plenum chamber in column 1.

One observation made on this particular day was the wind was from the east. This caused the air leaving the dryer to move toward the inlet and the fan pulled this air into the dryer through the burner. The air leaving the dryer had a certain amount of sunflower dust or fuzz in it, and this is believed to be the cause of the fires. In all other drying the wind was from the northwest, and so the air leaving the dryer did not enter the fan.

Pitch of the fan was changed to increase the plenum chamber air pressure while drying these sunflowers and the result was less accumulation of material in the plenum chamber. It was believed that this pressure increase was enough to greatly reduce the quantity of trash entering through the perforated walls. Later a large perforated cylinder was placed in the plenum chamber as a flame arrestor, but then the trash tended to accumulate in the plenum chamber again. Apparently the air pressure against the perforated wall was reduced enough to allow the trash to enter through the wall.

Temperature Variations During Drying

To get a better understanding of drying, the temperature variation with time will be discussed. Although numerous plots can be presented, only two represented plots will be discussed. In Figures 3 and 4 the temperatures are plotted for the lots dried on November 15 and the second lot dried on November 18, respectively. These temperatures are plotted only for columns 1 and 2.

The lot represented in Figure 3 had very little dockage. The air leaving was near 80°F and did not fluctuate very much above or below this level — 2°F at the most. Also the temperatures for columns 1 and 2 were very similar.

Looking at Figure 4, where the lot had a 12 per cent dockage, temperatures are much different. The air leaving column 2 was near 90°F but there were some large fluctuations from 102°F down to a minimum of 85°F. Looking at column 2 temperature curve, the temperature was as high as 149°F

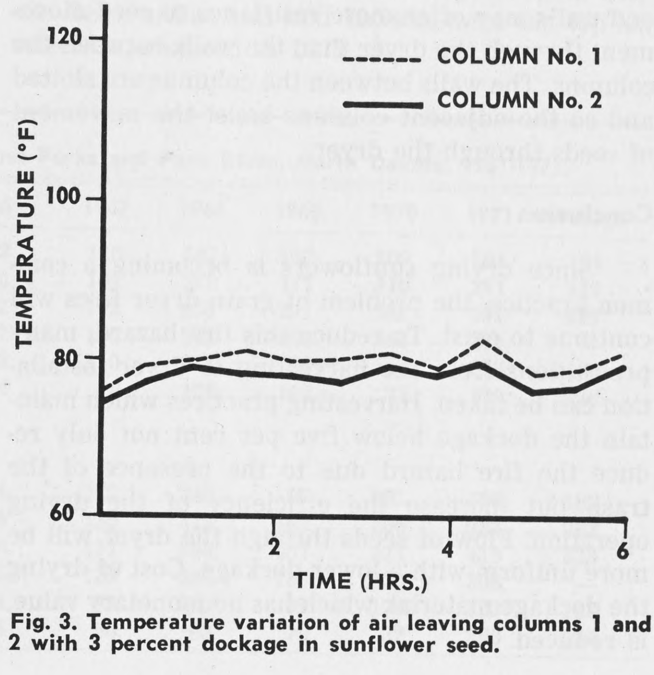

Fig. 3. Temperature variation of air leaving columns 1 and 2 with 3 percent dockage in sunflower seed.

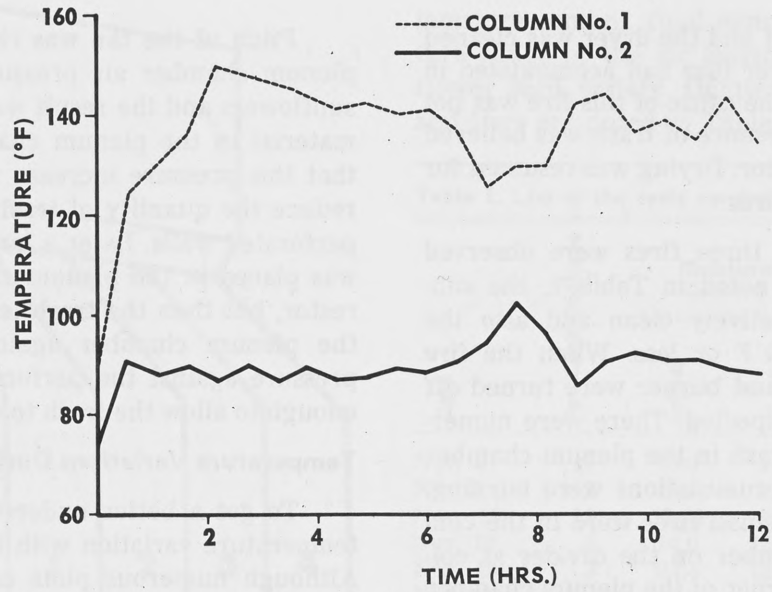

Fig. 4. Temperature variation of air leaving columns 1 and 2 with 12 percent dockage in sunflower seed.

and as low as 124°F during drying. These fluctuations are believed to be caused by uneven flow through the dryer and occurred when there is a large amount of trash with seeds. These large temperature fluctuations were characteristic of the sunflower seeds that had a large dockage.

Another point noted here was that the temperatures in the columns near the ends of the dryers had temperatures higher than the adjacent columns. This can be noted also in Figure 4 where column 1 had higher temperatures. One possible cause for the end columns to have higher temperatures is that they may have more trash in the seeds due to the methods of loading seeds into the dryer, or the end walls may offer more resistance to seed movement through the dryer than the walls between the columns. The walls between the columns are slotted and so the adjacent columns assist the movement of seeds through the dryer.

Conclusion

Since drying sunflowers is becoming a common practice, the problem of grain dryer fires will continue to exist. To reduce this fire hazard, many precautions from the harvesting to dryer installation can be taken. Harvesting practices which maintain the dockage below five per cent not only reduce the fire hazard due to the presence of the trash but increase the efficiency of the drying operation. Flow of seeds through the dryer will be more uniform with a lower dockage. Cost of drying the dockage material, which has no monetary value, is reduced.

When installing a dryer, the air inlet should be located to keep as much dust and other similar material out of the dryer as possible. Since the prevailing wind for the Red River Valley is from the northwest, the air inlet should be oriented in this direction when possible. If the inlet is near the ground, some type of large tubing should be adapted to draw clean air into the dryer. One manufacturer plans to put a large flexible tube on the inlet so that the tube is directed up-wind from the dryer for changing wind directions.

Design of the dryer could be altered to reduce the fire hazard, but in most cases the dryer efficiency would be reduced. Doing away with the open flame by using electric heat or some form of a heat exchanger would be desirable, but would result in increased drying costs. Increasing the distance between the plenum chamber and burner would improve open flame dryer design and reduce the possibility of fire. Hopefully, sunflower fuzz and dust would be burned out when it comes in contact with other materials in the plenum chamber.

Although there may not be a complete solution to the fire hazard, this study suggests practices which should reduce the hazard. Primary cause of the fires certainly appears to be in the material entering the chamber through the burner.

References

1. Koegel, R. G. and H. D. Bruhn. 1971. **Inherent causes of spontaneous ignition in silo.** Transactions of ASAE Vol. 14, No. 2, pp. 273-276, 281.

2. Sallans, H. R., G. D. Sinclair and R. K. Larmour. 1944. **The spontaneous heating of flaxseed and sunflower-seed stored under adiabatic conditions.** Canadian Journal of Research 22F pp. 181:190.