STORAGE OF HIGH MOISTURE GRAIN IN AN AIR-TIGHT BUTYL RUBBER BIN

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Grain is frequently harvested before it is adequately dried in the field because of poor weather conditions or other factors. In many cases, high moisture grain must be stored for some time before it can be dried, processed, or fed to livestock. Grain having a high moisture content deteriorates rapidly in storage due to mould growth and insect and mite infestations. One method of reducing deterioration is to store the grain in air-tight containers. Insects, mites, and aerobic fungi are rendered inactive or die as the oxygen in the container is consumed by the organisms' respiration. Grain containing 17 to 24% moisture remains free-flowing and mould free when stored in air-tight containers for up to five years; however, the grain is unacceptable for milling and baking because of a sour-sweet smell and bitter taste attributed to the growth of anaerobic organisms (2, 3). Cattle accept high moisture barley stored in airtight units more readily than dry barley, which results in earlier weight gains and better final carcass grades (4).

Before airtight storage units can be recommended for Western Canadian farmers, such units must be tested under the particular conditions of temperature, grain type, microflora, microfauna, and grain handling system existing in Western Canada. A butyl-rubber bin, which is used by farmers in England, was obtained and tested during the summer of 1969. The summer test period was chosen because the most rapid deterioration of grain occurs during the hot summer months. For comparison, a similar quantity of high moisture grain was stored in a galvanized steel bin.

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BIN DESCRIPTION

The test bin consisted of a bag made out of 0.03 in (0.76 mm) thick butyl rubber supported by a 2 in by 2 in (5.1 cm by 5.1 cm) welded mesh of No. 8 gauge galvanized steel (Figure 1). The manufacturer gives the following bin dimensions: wall height, 9 ft (2.7 m); centre height, 10.5 ft (3.2 m); diameter, 13 ft (4.0 m); capacity, 1,295 ft^3 (36.6 m^3); (about 1,000 bu or 27.2 metric tons). Because the collapsed bin package (Figure 2) is quite compact, it can be readily transported.

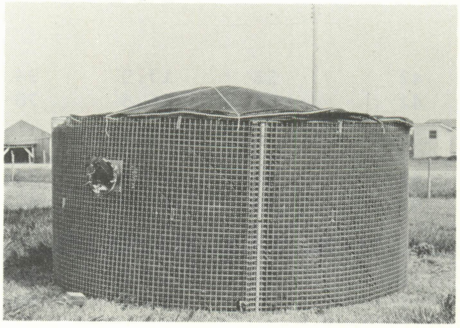

Figure 1 Butyl-rubber bin about two thirds full.

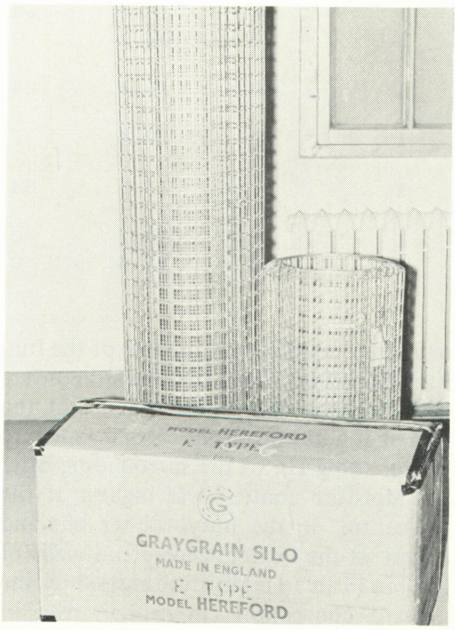

Figure 2 Butyl-rubber bin package.

The top of the bin has a plastic airtight zipper running about three-quarters of the way around the bin (Figure 3). The top is thrown back over the grain and zippered shut after the bin has been filled (Figure 1). An unloading pipe is set into the side of the bin in such a way that it extends on an angle to the centre of the bin. For unloading, an auger is pushed into this pipe. During storage a rubber sleeve is tied over the end of the unloading pipe to prevent moisture or air entering the bin (Figures 1 and 3).

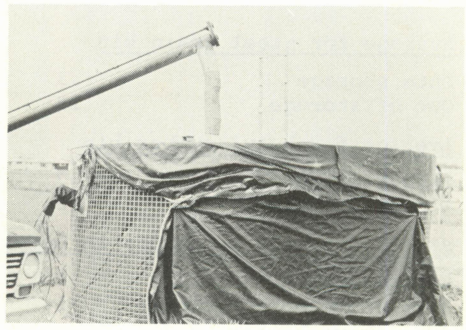

Figure 3 Open butyl-rubber bin.

TEST PROCEDURE

On June 5, 1969 the butyl-rubber bin was partially filled with 615 bu (16.7 metric tons) of hard red spring wheat which had been harvested damp the previous fall and stored throughout the winter without drying. The height of grain in the bin was approximately 6 ft (1.8 m) and the second tier of steel mesh was not installed (Figure 1). The bin remained closed until the grain was unloaded on September 2, 1969, after about 12-1/2 weeks of storage. For comparison, 430 bu (11.7 metric tons) of similar grain was stored in a steel bin from May 29, 1969 to August 26, 1969. The steel bin was 13.8 ft (4.2 m) in diameter and had a concrete floor.

Seven representative samples were taken as the butyl-rubber bin was filled. Ten samples were taken at representative locations throughout the bin as the grain was unloaded. A similar sampling of grain in the steel bin was also carried out.

Fungi and germination counts were made on the samples by the method described by Wallace and Sinha (5). Moisture contents were determined using a Halross 919 moisture meter, which had been checked against the Canadian Grain Research Laboratory standard. Temperatures were measured once a week with 55 copper-contstantan thermocouples located throughout the butyl-rubber bin and 49 thermocouples in the steel bin.

RESULTS AND DISCUSSION

The butyl-rubber bin was opened on September 2, 1969. A strong fermented odour was given off by the grain, but it appeared to be in good condition, except mouldy odour when unloaded, and was less free-flowing than that stored in the sealed bin.

Moisture content of the grain stored in the butyl-rubber bin changed only slightly from 19.3% to 19.9% during the storage period. The grain in the steel bin dried out from 17.9% to 16.5%. The grain went into the bins at a uniformly low temperature and was warmed up at the top and along the walls by external atmospheric heating. Under these conditions, Hall (1) indicated that there is an accumulation of moisture in the colder grain at the bottom-centre of the bin. In the steel bin there appeared to be no increase in moisture content at the bottom-centre of the bin, possibly because of the shallow grain depth of 3.5 ft (1.1 m). Grain along the walls and at the top dried of the bin because it could not escape into the outside air.

Temperatures measured throughout the butyl-rubber bin were generally above those of the steel bin between one and eight weeks of storage. Near the end of the storage period, the grain in the steel bin began to heat and its temperature rose rapidly above that in the butyl-rubber bin. The grain in the airtight bin did not appear to heat, although it had a higher moisture content than the grain in the steel bin. The largest difference between the maximum and minimum temperature readings at any of the grain depths in the bins, not including wall temperatures, was 8 F (4.5 C) for the readings on August 22, 1969. This indicates that localized hot spots were not developing in either bin.

TABLE I RESULTS FOR BUTYL-RUBBER BIN AND STEEL BIN

Description	Number of Samples	Number of thermo-couples	Temperature (F)	Moisture content (%)	Germination (%)	*Alternaria* (%)	*Penicillium* spp. (%)	*Aspergillus* spp. (%)
Average for steel grain bin								
Into storage	3	42	52	17.9	94	94	0	0
Out of storage	15	42	82	16.5	78	60	19	4
Average for butyl-rubber bin								
Into storage	7	42	52	19.3	84	86	0	0
Out of storage	10	42	78	19.9	40	8	2	2
Specific sample locations in butyl-rubber bin at end of storage period								
Bottom-centre	1	1	56	18.0	86	52	0	0
3 ft above bottom, centre	1	1	71	19.5	90	12	0	0
3 ft above bottom, 3 ft from northwall	1	1	71	19.7	76	8	0	0
3 ft above bottom, 3 ft from southwall	1	1	74	18.9	68	0	4	4
1 ft from top, centre	1	1	79	22.2	0	0	0	4
1 ft from top, 3 ft from eastwall	1	1	80	18.6	24	0	4	0
1 ft from top, 3 ft from westwall	1	1	83	19.4	2	0	4	4
1 ft from top, adjacent northwall	1	1	81	17.5	54	4	0	0
1 ft from top, adjacent southwall	1	1	80	18.2	0	0	8	0
Top-centre	1	1	83	27.5	0	8	0	4

for some mould on top of the grain where the zipper had been. Apparently some air had leaked into the bin along the zipper. At the very top of the pile some of the kernels were quite dark and moist. A one-inch diameter hole in the bin near ground level appeared to have been gnawed out by a rodent. Some grain had spoiled around the hole. In general, the grain was free-flowing and easy to handle. The grain stored in the steel bin had a strong out more rapidly than the rest of the bin. Vapour diffusion and the upward convection currents along the walls and at the top of the bin probably carried moisture out of the grain to the surrounding drier air. Moisture content was highest at the top-centre of the butyl-rubber bin and lowest at the bottom-centre and walls of the bin (Table I). Moisture carried by the upward convection currents in the airtight bin probably accumulated at the top

Thermocouples taped to the inner surface of the butyl-rubber bin showed that the rubber reached very high temperatures under the effect of solar radiation. During the storage period July 11, 1969 to August 15, 1969 six temperature recordings were taken at about 1:30 to 3:00 pm at approximately weekly intervals. At all of these sets of readings, the temperatures of the inner butyl-rubber surface at the top of the wall on the south and west sides of the bin, and at the centre-top of the bin were above 100 F (38 C). The highest measured temperatures were 131 F (56 C) on the top-south side of the wall on August 8, 1969, when outside shade temperature was 78 F (26 C); and 132 F (56 C) at the top-centre of the bin on July 11, 1969, when the outside shade temperature was 83 F (28 C). These are not necessarily peak temperatures because a continuous record was not taken. In comparison the highest wall temperature recorded in the steel bin was 99 F (37 C). In a nearby red plywood bin, which was being used for a different storage test with dry wheat, the inside surface of the south wall was at 102 F (39 C) on July 11, 1969. Inside surface of the plywood roof, which was not in contact with the grain, was 110 F (43 C). Grain stored in black butyl-rubber bins appears to be in contact with considerably higher temperatures than in either steel or wooden bins.

The average germination and *Alternaria* counts for the grain in the butyl-rubber bin dropped more during the storage period than did the counts for the grain stored in the steel bin (Table I). But the destructive storage fungi, *Penicillium* spp. and *Aspergillus* spp., also developed less in the butyl bin than in the steel bin. The results indicate that the butyl-rubber bin was airtight, and the high moisture grain did not begin to deteriorate due to the growth of the normal storage fungi. But the grain in the steel bin, which was at a lower moisture content, began to heat and the storage fungi began to grow throughout the bin.

The wheat, when put into the bins, was of satisfactory milling and baking quality. After storage in the butyl-bin the wheat had a distinct fermented odour which carried through to the baked loaf. The wheat in the steel bin had a strong mouldy odour and could not be used for milling and baking purposes.

General observations during the summer test period indicated some of the following major advantages and disadvantages of using a bin of this type on Western Canadian farms. Two untrained men can erect the bin relatively quickly and simply. No permanent foundations are required so the bin can be set up on any fairly flat location. The bin can be readily dismantled and moved from one location to another. The dismantled bin is not bulky and can be easily stored and then erected when and where required. Care must be taken during filling and emptying to prevent puncturing the butyl-rubber bag. Emptying the bin requires considerable hand shovelling, as is required in any similar flat-bottom wooden or steel bin. Although the butyl-rubber bin has a number of advantages, probably mechanical unloading systems would have to be designed to reduce the required hand labour, before this type of bin would be acceptable to the majority of Western Canadian farmers.

SUMMARY

The storage of high moisture wheat in an airtight butyl-rubber bin was compared with that in a typical steel bin during a 12-1/2 week summer period. The mean moisture content in the butyl-bin rose from 19.3% to 19.9%, but in the steel bin it decreased from 17.9% to 16.5%. In the butyl-rubber bin comparative temperatures, moisture contents, and germination percentages at the bottom-centre and top-centre of the bin were 56 F (13 C) and 83 F (28 C), 18% and 27.5%, 86% and 0%. The lowest germination occurred at the top-centre, top-south, and top-west sectors. The mean *Penicillium* and *Aspergillus* infections in the butyl-rubber bin were 2% and 2% and in the steel bin 19% and 4%, respectively. Grain from neither bin could be used for milling and baking purposes.

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REFERENCES

1. Hall, C.W. 1957. Drying farm crops. Agricultural Consulting Associates, Inc., Reynoldsburg, Ohio.
2. Hyde, M.B. 1962. Airtight storage of grain. Ann. Appl. Biol. 50: 362-364.
3. Hyde, M.B. and Oxley, T.A. 1960. Experiments on the airtight storage of damp grain. Ann. Appl. Biol. 48: 687-710.
4. Krall, J.L. 1969. High moisture barley harvesting, storing and feeding. Montana Agr. Exp. Sta. Bulletin 625.
5. Wallace, H.A.H. and Sinha, R.N. 1962. Fungi associated with hot spots in farm stored grain. Can. J. Plant Sci. 42: 130-141.