CONDITION OF WHEAT STORED IN SMALL AIRTIGHT AND OPEN CONTAINERS

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INTRODUCTION

A considerable amount of stored grain is spoiled by the growth of insects, mites, and fungi in the grain. Elevator managers in the three Prairie Provinces reported that in 1968-69 there were 24,038 cases of hot spots and insect and mite infestations in grain stored on farms (5).

Research carried out in many countries and thoroughly reviewed by Hyde and Burrell (3) shows that airtight storage has many advantages in the storing of both dry and damp grain. Airtight storage prevents the infestation and growth of insects and mites in dry grain. Airtight storage of damp grain retards or prevents the growth of aerobic fungi, insects, and mites but viability and baking quality deteriorate with time so that the grain can be used only for animal feed. The rate of deterioration of Canadian wheat stored in airtight containers at Canadian prairie temperatures has not been investigated. This article reports the results of such a study over a period of 44 wk using wheat of three moisture levels – 12.2, 17.7, and 21.6% (wet weight basis).

MATERIALS AND METHODS

Hard red spring wheat, cult Manitou, which had been harvested 1.5 yr earlier was used in the tests. The average protein content of the wheat was 13.8% (dry weight basis). The wheat had a density of 82 kg/hl and was graded by the Canadian Grain Commission Inspection Division as No. 1 Manitoba Northern. Initial moisture content was 12.2% (moisture contents are expressed as percent of the wet weight). The wheat was divided into three equal portions. Moisture contents of two portions were increased to 17.7 and 21.6% by mixing distilled water with the grain.

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The wheat was stored in 300 wide-mouth glass jars of 3.64-liter capacity. To obtain approximately equal volumes of grain in each jar for the moisture contents of 12.2, 17.7, and 21.6%, the jars were filled with 2,800, 2,400, and 2,300 g of wheat, respectively. One-half of the jars with their metal lids left loose were considered nonairtight or open to the air. The other jars were made airtight by tightening the lids and sealing with black plastic tape. One-half of the sealed and unsealed jars were stored in a heated building held at a relatively constant room temperature of 20-30°C (Figure 1). The remaining jars were stored in an unheated building exposed to outdoor temperatures of −29-25°C.

Thirty samples were taken as the grain was loaded into the containers on June 16, 1969. One jar from each of the 12 treatments (three moisture contents, two temperatures, and two gaseous conditions) was opened at 1-wk intervals during the first 12 wk of storage, and thereafter at 4-wk intervals up to 44 wk of storage.

Viability and fungal flora were determined for 50 seeds selected at random from each sample during the first 5 wk of storage. For samples taken thereafter, 25 seeds were selected. The seeds were incubated for 1 wk at room temperature (17-24°C) on filter paper saturated with water (6). Tests of milling and breadmaking quality were carried out according to approved methods of the American Association of Cereal Chemists (1). Baking quality was assessed with the remix test of Irvine and McMullan (4). Moisture contents were determined by drying samples of 25-30 g for 96 h at 100°C (2).

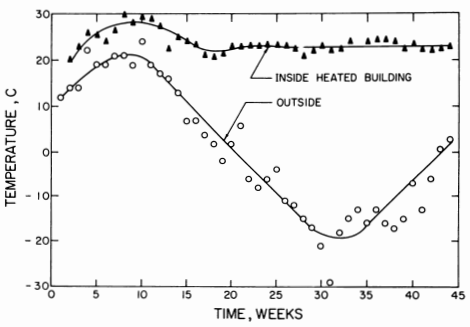

Figure 1. Temperature of container environment.

RESULTS

Moisture Content

In airtight containers the moisture content of wheat initially stored at 12.2, 17.7, and 21.6% moisture content increased about 0.5-1.0 percentage units during storage for 44 wk under both conditions of temperature.

In open containers the moisture content of wheat initially at 12.2 and 17.7% moisture content increased about 0.5 percentage units during storage at outdoor temperatures whereas there was a decrease of about 2-3 percentage units during storage at room temperature. Wheat initially at 21.6% increased to over 35% at outdoor temperatures and to 30% at room temperature during 20 wk of storage in open containers. This increase in moisture was probably due mainly to the respiration of fungi throughout the grain.

Viability

The viability of wheat stored at 12.2% moisture content remained at or near 100% during storage at all conditions (Figures 2 and 3). Although wheat of higher moisture contents decreased in viability for all storage conditions there was a different response for sealed and open containers. In the airtight containers the wheat retained a high level of viability for about 5 wk or more, and then declined rapidly. In the open containers loss of viability was immediate but not so rapid. Grain exposed to outdoor temperatures had a higher viability than grain stored at room temperature.

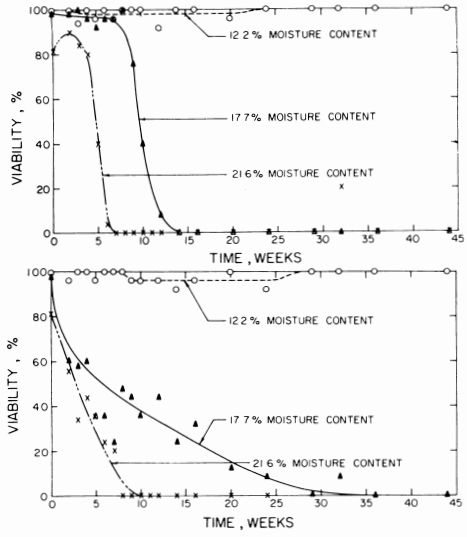

Figure 2. Viability of wheat stored in airtight containers (*top*) and open containers (*bottom*) at room temperature of 20-30°C.

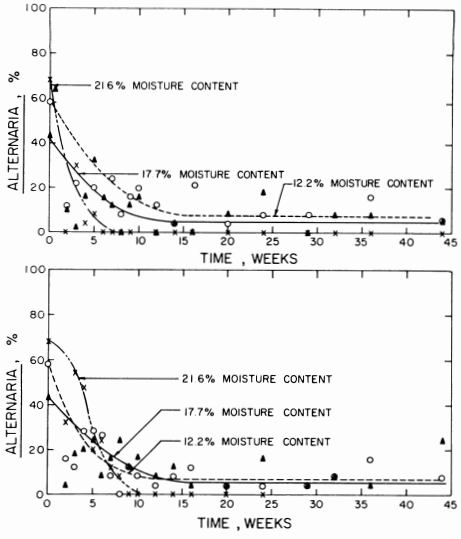

Figure 4. Frequency of occurrence of *Alternaria* on wheat seeds stored in airtight containers (*top*) and open containers (*bottom*) at outdoor temperatures.

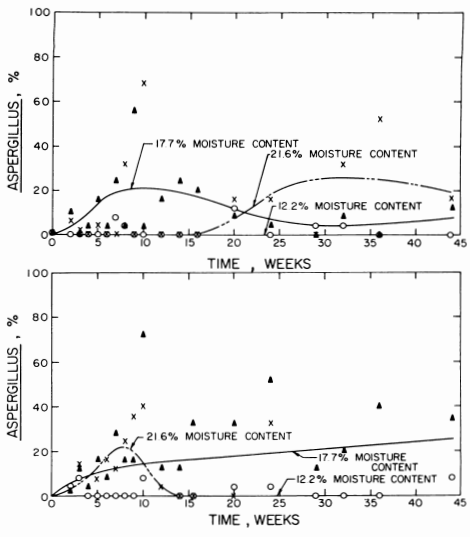

Figure 6. Frequency of occurrence of *Aspergillus* on wheat seeds stored in airtight containers (*top*) and open containers (*bottom*) at outdoor temperatures.

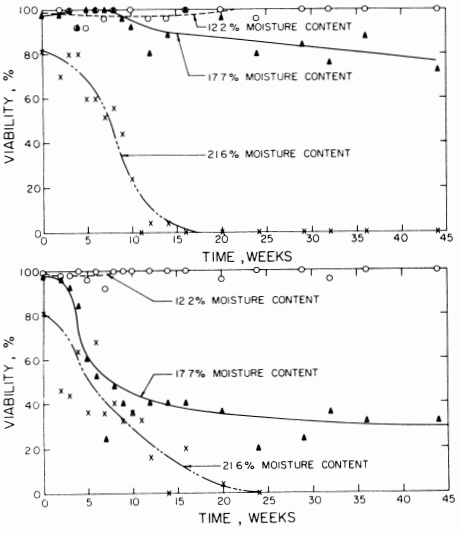

Figure 3. Viability of wheat stored in airtight containers (*top*) and open containers (*bottom*) at outdoor temperatures.

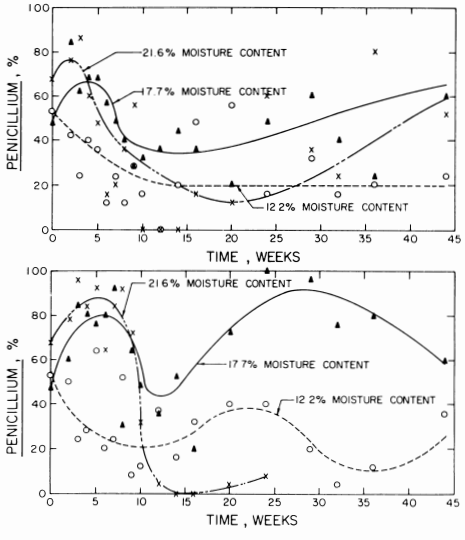

Figure 5. Frequency of occurrence of *Penicillium* on wheat seeds stored in airtight containers (*top*) and open containers (*bottom*) at outdoor temperatures.

Fungi Infection

The abundance of *Alternaria alternata* (Fr.) Keissler decreased rapidly in wheat stored under all conditions of moisture content, temperature, and type of container (Figure 4). This field fungus, which decreases as the age and deterioration of the grain increases, persisted slightly longer in containers kept outside (lower temperatures) than in containers stored in the heated building.

Initially the wheat was heavily contaminated with *Penicillium* spp. but had a very low level of contamination by the other main genus of storage mold, *Aspergillus* (Figures 5 and 6). *Penicillium* continued to predominate over *Aspergillus* throughout the test period. The abundance of *Penicillium* was not greatly affected by the difference in temperature, but *Aspergillus* was lower in samples stored at lower temperatures. *Aspergillus* was slightly higher in the unsealed jars than in the sealed jars but the amount of *Penicillium* was the same in all types of containers.

Odor and Cohesiveness

Grain containing 21.6 and 17.7% moisture developed a strong moldy unpleasant odor within 2 wk when stored in open containers; grain stored in airtight containers had only a slight fermentation odor. Grain containing 12.2% moisture maintained a normal healthy odor throughout the 44 wk of storage in both airtight and open containers.

Under both conditions of temperature grain containing 21.6% moisture stored in sealed jars was cohesive after 2 wk of storage but with a small amount of shaking the grain became free-flowing even after 44 wk of storage. The 21.6% moisture content grain stored in the open jars was cohesive and nonflowing after only 2 wk of storage. Grain containing 17.7% moisture stored in both sealed and unsealed jars exhibited some cohesiveness but was easily loosened. Grain containing 12.2% moisture remained free-flowing throughout the storage period.

Milling and Breadmaking Quality

For samples that had not visibly deteriorated, milling quality, as indicated by flour yield and ash content of the flour, did not show any marked change with storage. Some of the high-moisture samples stored for prolonged periods showed obvious mold growth and therefore were not milled.

Breadmaking quality was assessed using the sedimentation, baking, and farinograph tests (Tables I-IV). The farinograph results did not show definite changes with storage time and are therefore not included in the tables.

Wheat stored in airtight jars at room temperature showed marked deterioration in baking quality with increasing moisture and storage time (Table I). Wheat stored at 12.2% moisture content

TABLE I SAMPLES STORED IN AIRTIGHT JARS AT ROOM TEMPERATURE (SEDIMENTATION VALUE AND LOAF VALUE IN CM^3)

Storage period (wk)	Moisture content (%) 12.2 Sed. value	12.2 Loaf vol	17.7 Sed. value	17.7 Loaf vol	21.6 Sed. value	21.6 Loaf vol
0	49.5	820	49.0	775	54.0	880
8	43.5	773	43.5	758	34.5	660
24	37.5	810	†	†	‡	‡
41	38.0	738	29.5	490	‡	‡

† Sample lost in milling.
‡ Wheat deteriorated; could not be milled.

TABLE II SAMPLES STORED IN OPEN JARS AT ROOM TEMPERATURE (SEDIMENTATION VALUE AND LOAF VOLUME IN CM^3)

Storage period (wk)	Moisture content (%) 12.2 Sed. value	12.2 Loaf vol	17.7 Sed. value	17.7 Loaf vol	21.6 Sed. value	21.6 Loaf vol
0	49.5	820	49.0	775	54.0	880
24	39.0	818	37.0	†	‡	‡
41	38.0	843	34.7	†	‡	‡

† Flour did not form dough; could not be baked.
‡ Wheat deteriorated; could not be milled.

TABLE III SAMPLES STORED IN AIRTIGHT JARS AT OUTDOOR TEMPERATURES (SEDIMENTATION VALUE AND LOAF VOLUME IN CM^3)

Storage period (wk)	Moisture content (%) 12.2 Sed. value	12.2 Loaf vol	17.7 Sed. value	17.7 Loaf vol	21.6 Sed. value	21.6 Loaf vol
0	49.5	820	49.0	775	54.0	880
24	43.5	875	43.2	860	†	†
41	44.5	753	43.1	825	†	†

† Wheat deteriorated; could not be milled.

TABLE IV SAMPLES STORED IN OPEN JARS AT OUTDOOR TEMPERATURES (SEDIMENTATION VALUE AND LOAF VOLUME IN CM^3)

Storage period (wk)	Moisture content (%) 12.2 Sed. value	12.2 Loaf vol	17.7 Sed. value	17.7 Loaf vol	21.6 Sed. value	21.6 Loaf vol
0	49.5	820	49.0	775	54.0	880
24	42.3	805	43.5	773	†	†
41	42.9	818	43.3	670	†	†

† Wheat deteriorated; could not be milled.

retained its original quality up to 41 wk of storage.

Wheat stored at room temperature in open jars deteriorated faster at the two higher moisture content levels than wheat stored in airtight jars (Table II). The 24- and 41-wk samples at 17.5% moisture content were milled but the flour would not form into a dough for the baking test. Analogous samples at the highest moisture content were completely unacceptable for milling. Wheat at 12.2% moisture content remained unchanged during the 41 wk of storage investigated.

The rate of deterioration was lower in the samples of wheat stored at outdoor temperatures (Tables III and IV). Airtight environment was definitely superior to open environment under outdoor conditions. Wheat of 17.7% moisture content retained its initial quality for 41 wk when stored in airtight jars. In open jars, grain at this moisture content showed a gradual drop in quality but even after 41 wk the flour could be processed into bread, although its quality was marginal. Wheat stored initially at 21.6% moisture content deteriorated rapidly and could not be milled after the initial sampling.

DISCUSSION

The quality of grain stored at 17.7 and 21.6% moisture content changed most rapidly during the first few weeks of storage. Although the test was begun in June, the mean outside temperature during these first few weeks was equal to or higher than that after harvesting in August. Because the wheat was 1.5 yr old, the abundance of *Penicillium* at the beginning of the test period was greater than would be normally expected in freshly harvested grain. For these reasons we suggest that newly harvested grain stored in August would deteriorate at an equal or slower rate than the grain in this test.

The test results indicate that grain harvested damp can be stored in airtight containers for short periods without loss of viability or milling and baking quality. The use of airtight storage for short periods could allow a farmer to harvest damp grain and use a low-capacity grain dryer.

The viability, milling, and baking qualities of dry grain (12.2% moisture content) remained high throughout the storage period under all test conditions. In dry grain stored in airtight containers insect and mite infestations are prevented by asphyxiation of existing infestations as well as by protection from external in-

festations. During long-term storage, moisture may migrate in large bulks of dry grain and may accumulate at one or more locations in the grain bin. Airtight storage would probably limit mold growth in these pockets of high-moisture grain whereas in nonairtight storage rapid deterioration could occur as these hot spots develop.

SUMMARY

Wheat containing 12.2, 17.7, and 21.6 percent moisture was stored for 44 weeks in airtight and open containers. One-half of the containers were at room temperature of 20 to 30 degrees Celsius while the others were at outside temperatures of minus 29 to 25 degrees Celsius.

Viability of wheat stored at 12.2 percent moisture content remained high during storage at all conditions. Viability of wheat initially at 17.7 and 21.6 percent moisture content dropped immediately after initiation of storage in open containers but remained high for a few weeks in airtight containers. Grain stored at the lower outdoor temperatures retained a higher viability than grain stored at room temperature. Milling and baking tests confirmed the viability results.

ACKNOWLEDGEMENTS

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