GERMINATION OF FROZEN AND NONFROZEN WHEAT HARVESTED AT VARIOUS STAGES OF MATURITY

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INTRODUCTION

In the northern part of the United States, and especially in the Rocky Mountain region and in western Canada, where the growing season is relatively short, spring wheat is frequently subjected to temperatures below freezing at immature stages of growth. Kernels threshed from frosted wheat may be recognized by the blistered or wrinkled appearance of the outer layers of the bran and by their green pigmentation. Usually the more immature the wheat at the time of frost the greater the number of green kernels. The green kernels may not be blistered.

Lugger (10) attempted to distinguish between frosted and frozen wheat. He states:

We see at once the important difference between frosted wheat and frozen wheat. In the former germination may take place in most cases; in the latter never, because the living substance of the seed, the protoplasm, is dead and can not be resurrected by any known means.

Harper (7) states more clearly the difference, saying:

Frozen wheat is badly shrunken, has lost the normal translucent amber color, is of an opaque bronzed appearance, and has had the composition of its chemical constituents changed as well as the internal structure of its cells destroyed.

Blistered (frosted) wheat retains the normal amber color, but has in many cases more gluten and protein and less starch than sound wheat, and is injured for mill- ing on account of the bad condition of the hull. Only in extreme cases has there been any injury to the germ and its surrounding food, so that it is all right for seed, if well cleaned, except in some cases where frost has caused the injury because of the tardiness of the wheat to mature.

Green (5) tested the germination of frosted wheat in soil in the greenhouse. He found that the germination in the series of graded frosted wheats which he investigated ranged from 68 to 92 per cent. The lowest value found for 8 samples of wheat classed as chicken feed was 42 per cent. Some of these samples had been injured by both frost and rust.

Keffer (8) examined 13 samples of wheat. He determined the percentages of "plump," "slightly shriveled," and "much shriveled" kernels in each sample. Seven samples which contained 50 per cent or more of much shriveled kernels and averaged 72 per cent gave an average germination of 72 per cent in soil and 82 per cent between moist papers. Three samples with a content of much shriveled kernels ranging from 29 to 47 per cent gave an average germination of about 76 per cent in soil and 91 per cent between moist papers. The wheat which he reported as normal contained 5 per cent of much shriveled kernels and gave a germination of 82 per cent in soil and 99 per cent between moist papers.
Atkinson, Whitlock, and Jahnke (1) investigated the seed value of frosted wheat. They separated into two parts each of 32 samples of wheat which contained a large percentage of frosted kernels, one containing only kernels showing frost injury and the other containing kernels showing no frost injury. The germination of these samples was tested in the field. The average germination of the frosted samples was 75 per cent and that of the nonfrosted 78 per cent. Their results show a greater number of heads per row and a higher yield from the frosted kernels. They state:

The difference is not great enough to be very significant, yet it shows that kernels showing frost injury are not necessarily worthless for seed. It should be understood that grain may be entirely destroyed by frost, so far as its seed value is concerned, but this test suggests that all grain need not be discarded for seed purposes because it shows frost injury. The only safe plan is to have it tested before deciding either to use or discard it.

Atkinson and Jahnke (2) carried out further investigations on the germination of frosted wheat along somewhat the same line. The report of their experiments indicates that the frosted wheat showed a less germination than the nonfrosted wheat separated from the same samples.

Miss Lute (11) states that frosted wheat from San Luis Valley, Colo., showed low germination, but gives no definite data on the subject.

The effect of freezing temperatures produced by artificial means on the germination of seeds has been studied by a number of investigators. Detmer (4) states that air-dry wheat kernels can be subjected to temperatures of $-5^\circ$ to $-10^\circ$ C. without injuring their germination, while if the turgid kernels are subjected to these temperatures the germination is injured. Thiselton-Dyer (13) found that air-dry wheat kernels could be subjected to the temperature of liquid hydrogen for 1 hour without injuring their germination. Becquerel (5) subjected air-dry wheat kernels to liquid air for 130 hours and found that germination was unimpaired after this treatment.

**EXPERIMENTAL DATA**

A part of a 1923 crop of Marquis wheat was purchased from a farmer living near the Montana Agricultural Experiment Station. This wheat was grown under a system of dry farming. Portions of the wheat were harvested at intervals of two to four days during the development of the kernel. In order to restrict the amount of material flowing into the kernel after harvest, only the heads were gathered. Enough heads were obtained at a time to fill six 24-pound flour sacks. Three of these sacks were placed in the hardening room of an ice-cream manufacturing plant for 48 hours, after which time they were spread on the floor of a large room to dry. The other three sacks picked at the same time were at once spread on the floor to dry. The temperature of the hardening room ranged between $-20^\circ$ and $-28^\circ$ C. After the heads became dry they were threshed.

The moisture content of the kernels was determined at the time of harvest. The values obtained are given in Table I. The weight per kernel was calculated from the weight of 1,000 kernels. Typical frozen and nonfrozen kernels at four stages of development were photographed (pl. 1). Estimating the age of the kernels from the...
Germination of Frozen and Nonfrozen Wheat

Data given by Sharp (12) for the development of Marquis wheat obtained in a similar experiment the previous year, it is probable that the kernels in samples 131 and 132 (see Table I) are about 13 days old. In the previous year (Table I of the paper by Sharp) kernels 13 days old contained 70.7 per cent moisture and weighed 7.9 mgms., while sample 131 contained 69.4 per cent moisture at the time of harvest and the dry weight per kernel was 7.7 mgms. This estimated age of the kernel is probably correct to within one or two days. The kernels representative of sample 131, Plate 1, A, have the yellow color of mature wheat, the kernels from the sample 132, Plate 1, B, which was collected at the same stage of maturity but which was frozen before drying, are entirely green in color. Samples 137 C and 138 D in Plate 1 were collected 12 days later and therefore are approximately 25 days old. The frozen kernels, 138, still show some green color, and blistering of the outer bran layers is apparent. Samples 141, Plate 1, E, and 142, Plate 1, F, were approximately 29 days old; at this stage of development no green kernels were found in the frozen sample; the blistering of the outer layers of the bran was greatest during this period of development. Sample 149, Plate 1, G, and sample 150, Plate 1, H, were approximately 38 days old, and blistering of the frozen kernels was still marked. Samples 149 and 150 were collected five days after the time the farmer considered the best for cutting the main part of his field of wheat. Thus the farmer decided to cut his wheat when the kernels were approximately 33 days old. Sample 152 also showed marked blistering. It is thus apparent that blistering may be produced by severe freezing even when the moisture content of the wheat is 34 per cent or less. Possibly if the freezing temperature had been less severe blistering might not have occurred at such a low moisture content. Farmers frequently believe that their wheat is safe from frost damage as soon as it is in the shock. Whether or not wheat is safe from frost damage probably depends on the moisture content of the kernel and the freezing temperature and its duration. Additional data on this series of wheat are given by Sharp (12) and will not be repeated here.
Kernels of frozen and nonfrozen wheat harvested at various stages of maturity

A. — Sample No. 131, nonfrozen, approximate age, 13 days
B. — Sample No. 132, frozen, approximate age, 13 days
C. — Sample No. 137, nonfrozen, approximate age, 26 days
D. — Sample No. 138, frozen, approximate age, 25 days
E. — Sample No. 141, nonfrozen, approximate age, 29 days
F. — Sample No. 142, frozen, approximate age, 29 days
G. — Sample No. 149, nonfrozen, approximate age, 38 days
H. — Sample No. 150, frozen, approximate age, 38 days
Germination tests as described by Whitcomb (14) were made on November 24 and December 21, 1923, and November 22, 1924, by the alternating-temperature method. This test, as carried out, consisted in placing 100 kernels between pieces of moist blotting paper and keeping them for 18 hours at 20° C., and then raising the temperature to 30° C. for six hours, and then lowering it to 20° C. for 18 hours, etc. On December 21, 1923, the germination was determined also by the ice-box method. In this method 100 kernels were placed between moist blotting papers, and kept continuously in the ice box at 4° to 6° C. for five days, at the end of which time the wheat was treated by the alternating-temperature method as described above. The tests were all carried out in duplicate. The results are given in Table I.

Table I.—Marquis wheat: Germination of frozen (temperature —20° to —28° C.) and nonfrozen wheat harvested at various stages of maturity

[Harvest began Aug. 9, 1923, when the kernels were about 13 days old. The germination tests were all run on duplicates of 100 kernels. Where 0.5 per cent occurred in the average it was added as 1 per cent]

<table>
<thead>
<tr>
<th>Laboratory No.</th>
<th>Approximate age of kernel</th>
<th>Moisture at time of harvest</th>
<th>Weight per kernel, moisture-free</th>
<th>Germination</th>
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<td>Nov. 24, alternat-ing temperature 20° to 30° C., 9 days</td>
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<td>Per cent</td>
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<td>152, frozen</td>
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1 Main part of field harvested.

The effect of freezing the kernels on their germination on November 24, 1923, is apparent in all of the stages of development studied. The germination of the nonfrozen samples was very high throughout the whole range. The germination tests carried out about a month later show a great increase in the germination of those frozen samples which had a moisture content of 50 per cent or less at the time of freezing. After aging for more than a year the germination of the frozen samples had decreased markedly, while the nonfrozen samples
decreased in germination only slightly or not at all. Table I shows very clearly the pronounced effect of aging on the germination of frozen wheat, the germination being at first relatively low, increasing to a maximum, and then decreasing, so that at the end of a year the germination is again relatively low. The germination of the wheat which was more mature at the time of frost was less affected by freezing than was the more immature wheat. It would seem from an examination of Table I that if frosted wheat is to be used for seed it should be tested for germination immediately before seeding. Comparisons of the effects produced by subjecting seeds to freezing temperatures should include aging experiments.

Kiesselbach and Ratcliff (9) studied the effect on germination of subjecting immature corn to freezing temperatures. Their results show clearly that at a given moisture content the injury increases as the freezing temperature is lowered, and that "death from freezing is directly related to the moisture content of the kernel and also to the duration of the exposure to cold."

The wheat used in this investigation was subjected to freezing temperatures considerably lower than wheat would normally encounter in the field. These low temperatures were chosen intentionally, for the reason that if no effect was produced under these conditions then no effect would be expected under less severe ones. The results indicate the desirability of investigating the effect of less severe freezing temperatures.

Attention is called to the almost complete germination of the nonfrozen wheat at all of the stages of development studied. Even when the kernel was only approximately 13 days old germination was practically complete. The investigations of Harlan and Pope (6) on the germination of barley harvested at different stages of growth are of interest in this connection. These investigators hand-pollinated Hannchen barley so that they knew the exact age of the kernel to within one hour. They found no germination on the fourth day, but on the fifth day 9 out of 10 kernels germinated. The dry matter content of the Hannchen barley at 6 days of age was given as about 5 mgms. Kiesselbach and Ratcliff (9), in studying seed corn production, found that "the power of germination is attained in about 20 days after fertilization."

The germination tests carried out by the ice-box method December 21, 1923, gave only slightly different results from the alternating-temperature method.

Photographs of the germinated kernels from the test of December 21, 1923, using the alternating-temperature method for samples 131 and 132, are given in Plate 2; for samples 137 and 138, in Plate 3; and for samples 149 and 150, in Plate 4. These plates give an indication of the probable strength of the plant produced. There is apparently a greater development in the more mature samples.
Germination tests of wheat made December 21, 1923, by the alternating-temperature method

A. — Sample No. 131, nonfrozen wheat germination, 95 per cent
B. — Sample No. 132, frozen wheat germination, 2 per cent

Approximate age of kernels, 13 days
Germination tests of wheat made December 21, 1923, by the alternating-temperature method

A.—Sample No. 137, nonfrozen wheat germination, 100 per cent
B.—Sample No. 138, frozen wheat germination, 72 per cent

Approximate age of kernels, 25 days
Germination tests of wheat made December 21, 1923, by the alternating-temperature method

A.—Sample No. 149, nonfrozen wheat germination, 100 per cent
B.—Sample No. 150, frozen wheat germination, 89 per cent

Approximate age of kernels, 38 days
CONCLUSIONS

Very immature wheat shows almost perfect germination. Freezing impairs the germination of wheat less the more mature the wheat is at the time of freezing. The germination of frosted wheat is greatly affected by aging. The germination is at first relatively low, increases with time to a maximum, and then decreases to a low degree. Frosted wheat should be tested for germination immediately before seeding.

LITERATURE CITED