

Effect of Common Fumigants on the Baking Qualities of Wheat¹

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ABSTRACT

The effect of fumigation on the baking quality of HRW wheat of 12.5 to 13.5% moisture content was investigated. The following fumigants were used: Calandrex (a mixture of trichloroethylene:carbon tetrachloride:carbon bisulfide, 64:10:26, w./w./w.), trichloroethylene, carbon tetrachloride, carbon bisulfide, and methyl bromide. Investigations with Calandrex, as well as the mixture carbon tetrachloride:methyl bromide (80:20 w./w.), were also carried out in repeated fumigations on HRS wheat of 12.0 to 13.0% moisture content. Except for carbon bisulfide and to a minor degree Calandrex, no deleterious effects were caused by the treatments. Successive fumigations of wheat with Calandrex resulted in a marked decrease of loaf volume, the most pronounced effect being shown after the third fumigation. No effect was observed when wheat was repeatedly fumigated with the carbon tetrachloride:methyl bromide mixture.

The preservation of wheat reserves from insect infestation in subtropical countries requires proper control treatments, among which fumigation is the most commonly used. In Israel most of the wheat is stored in grain silos, in bulk, and fumigation at least once a year becomes necessary when storage is prolonged.

Information on the possible effect of fumigation on the baking quality of wheat is scattered throughout the literature and is incomplete. Dean and Swanson (1) treated wheat flour with carbon bisulfide and concluded that "the effects of fumigation are so small as to be negligible. It is only in the careful measurements employed in the test that any difference between the fumigated and unfumigated flour is apparent at all. The only notable difference appears in the maximum volume of the dough in the test made immediately after the fumigation, but not after 30 days. The finished loaf shows no deleterious effect from fumigation in any of the tests."

In experiments on the effect of fumigation on flour, Hermitte and Shellenberger (2) found no lasting deleterious effect at normal concentrations, 2 lb. methyl bromide per 1,000 cu. ft. Irreversible changes, however, were detected when excessively high concentrations of 25 lb. per 1,000 cu. ft. were employed.

Burns Brown et al. (3), dealing with the same subject, found serious tainting of the flour when excessive dosages of methyl bromide were used. They also found some discoloring even with normal dosages when the hot bread was removed from the oven. However, its taste after cooling seemed unaffected. These authors believe the risks of fumigation to be very slight, provided no repeated fumigations be carried out.

To our knowledge the only information concerned with the effect of fumigation of wheat grain on its baking qualities is found in the work of Larmour and Bergsteinsson (4), who concluded that excessive dosages of carbon tetrachloride were detrimental when grain of high moisture content was fumigated.

The aim of this work was to investigate the influence, so far unknown, of the

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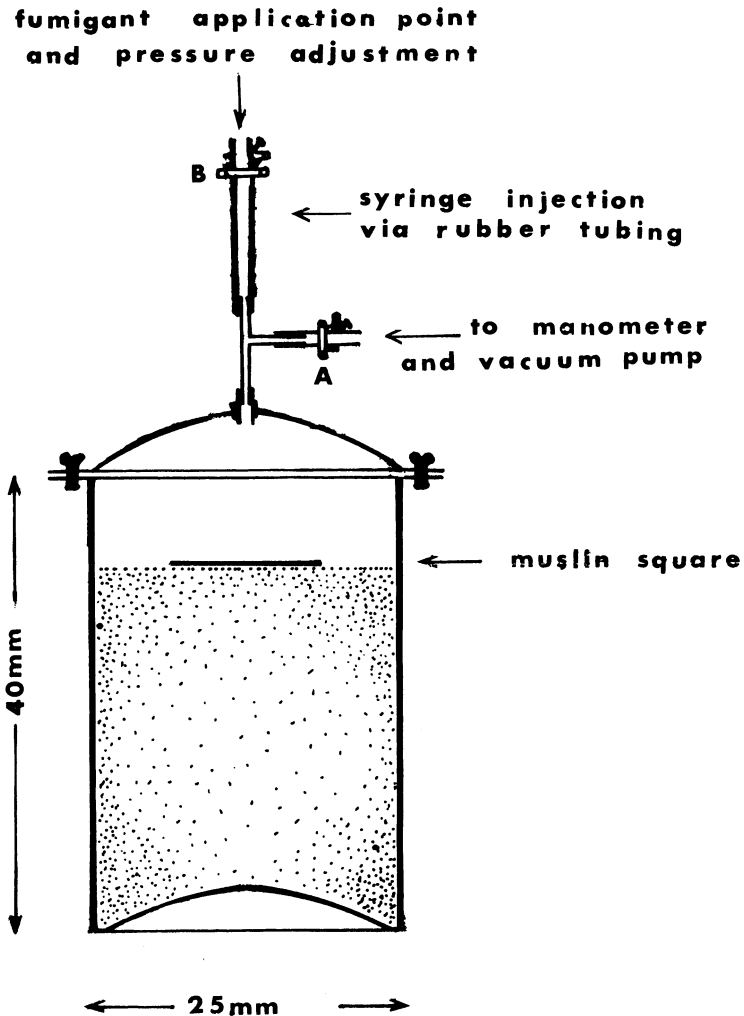


Fig. 1. Fumigation container and apparatus for application of fumigant.

fumigant mixture Calandex (trichloroethylene:carbon tetrachloride:carbon bisulfide, 64:10:26, w./w./w.) most commonly used in this country, and to compare it with the universally used methyl bromide.

MATERIALS AND METHODS

Cylindrical iron containers of 20-liter capacity (see Fig. 1) were used as fumigation chambers. Later fumigations were carried out with 30-liter containers to provide for more samples kept in reserve. The containers were equipped with flanged lids that could be clamped against a rubber gasket set in a flange of the

TABLE I. FUMIGANT, CONCENTRATIONS, AND EXPOSURE TIME USED IN TESTING THE EFFECT OF FUMIGATION ON THE BAKING QUALITIES OF WHEAT EXPOSURE TIME, 72 HR.

Fumigant	Concentration g./cu. m.
Calandrex (liquid fumigant mixture)	250
Carbon bisulfide	250
Carbon tetrachloride	250
Trichloroethylene	250
Methyl bromide	50
Carbon tetrachloride:methyl bromide ^a	200

^aUsed only in successive fumigations (second series).

container to obtain a gas-tight seal. The exposure time and dosages used are given in Table I.

Two series of fumigations were carried out; in the first, Calandrex, its components, and methyl bromide were tested. Baking quality tests were carried out on samples taken from each container after 1 week, and again 3 to 4 months after fumigation. The fumigations and the tests, in this series, were carried out on four replicates.

In the second series three successive fumigations were carried out at intervals of 3 months, and samples were drawn within a week after completion of the fumigation. Three replicates were carried out in this series. All samples consisted of 4 kg. of wheat, and were obtained with a small hand probe inserted repeatedly into the wheat columns.

Technique

The containers were sealed and evacuated to 56 cm. Hg via tubing entering the container through a rubber bung in the center of the lid (see Fig. 1). With clamps A and B closed, the measured amounts of fumigant were injected by syringe; or the fumigant was introduced by pipet at B with clamp B open. Atmospheric pressure was restored with clamp B open and the container was then resealed by removing the tubing and replacing with a rubber bung. For application of methyl bromide the required quantity was measured in a sealed buret held in a bath containing water and ice and then sucked into the container through tubing connected to B. To prevent sorption of the liquid fumigant by the grain, a muslin square was placed on the grain surface directly beneath the point of application.

Wheat

Imported HRW wheat of moisture content varying from 12.5 to 13.5% was used for the first series of fumigations and hard spring wheat of moisture content from 12.0 to 13.0% was used for the second series. The metal containers were kept in a constant-temperature room ($26^{\circ}\pm 2^{\circ}\text{C.}$) during and after fumigation. After exposure, the containers were opened and covered with muslin to prevent infestation.

Equipment and Tests

The samples were tempered overnight at 15% moisture content and milled in a Buhler laboratory mill.

The following equipment and tests were used to evaluate the influence of the fumigants on the baking quality of the wheat: farinograph (constant flour weight methods), to ascertain whether there is any detrimental effect on the mixing characteristics or gluten development in the dough; extensigraph, to measure the influence on the dough extensibility; amylograph, to evaluate any possible effect on the diastatic activity of the flour; and baking test as the final criterion for evaluating baking quality.

The baking tests were performed according to the following standard method that approaches closely the commercial procedure for bread production in this country:

Ingredients: 800 g. flour, 10 g. salt, 8 g. dry yeast dissolved in 80 g. 4% sugar solution, and 200 p.p.m. potassium bromate.

Water is added as required for correct consistency and the dough is mixed for 5 min. in a Hobart mixer at medium speed. The dough is allowed to ferment for 2-hr. in a fermentation cabinet at 30°C. and 90 to 100% r.h., is given a first punch after 1 hr. and is left for a recovery period of 1 hr. additional. At the end of this period the dough is taken out and scaled to 580 g. (as a multiple charge is used). The two doughs are roughly moulded up into round balls, placed on the board (covered), and allowed to stand for about 5 min. Then the doughs are moulded, put into pans, and placed in the fermentation cabinet for final proofing (proofing time, 75 min.). Baking is done at 220°C. to constant weight (500 g.). When the loaf has cooled the volume is measured in a loaf volumeter by rapeseed displacement.

The second series of fumigations were subjected to the baking test only.

RESULTS

Effect of Fumigants on Baking Quality of Wheat

Data obtained from the farinograph, extensigraph, and amylograph are summarized in Table II. While some differences are evident, the effects of the fumigations were not detected with any degree of significance except for carbon bisulfide. The extensigraph test performed on the sample drawn a week after fumigation shows clearly a detrimental influence caused by carbon bisulfide on the elasticity of the dough, which becomes weak and runny. This clear effect was not observed in tests on the sample drawn after 3 to 4 months. As shown in Table II, the data obtained from the farinograph and amylograph tests failed to reveal any detrimental effect.

The results of the baking tests as expressed by loaf volume are given in Fig. 2, and the following conclusions can be drawn:

- 1) Slightly different values are obtained for different fumigants.
- 2) The most markedly negative effect is obtained by treatment with the Calandrex mixture and with carbon bisulfide.
- 3) The baking quality of wheat does not seem to be affected by methyl bromide treatment.
- 4) The above effects remain almost without change for 3 months after treatment.

TABLE II. EFFECT OF FUMIGATION ON BAKING QUALITY OF WHEAT

	Time after Fumigation	Farinograph			Amylograph, Diastatic Activity B.U.	Extensigraph			
		Absorption %	Consistency Drop B.U.	Development Time min.		Length cm.	Height at 5 min. B.U.	Maximum Height B.U.	Area sq. cm.
Control	1 week	58.5±0.78 ^a	65.0± 6.44	6.25±0.24	773.7±24.7	15.87±0.48	610.0± 45.1	903.7± 52.5	175.2± 8.48
Calandrex		58.8±0.72	71.5± 5.12	6.25±0.42	782.5±40.9	16.87±0.85	482.5± 38.5	751.2± 30.4	161.3± 7.61
Carbon bisulfide		59.8±0.60 ^b	67.5± 9.60 ^b	6.50±0.50 ^b	790.0±50.3 ^b	18.00±1.74 ^b	436.6± 52.4 ^b	690.0± 57.9 ^b	157.3± 3.67 ^b
Trichloroethylene		59.0±0.49 ^b	66.5± 6.65 ^b	6.66±0.43 ^b	776.6±51.7 ^b	16.75±0.24 ^b	498.3± 14.5 ^b	801.6± 20.3 ^b	164.6± 2.35 ^b
Carbon tetrachloride		59.2±0.84 ^b	56.7± 3.40 ^b	6.66±0.43 ^b	776.6±43.9 ^b	15.58±0.30 ^b	611.6± 82.4 ^b	885.0± 79.7 ^b	171.6± 6.89 ^b
Methyl bromide		59.7±1.40	60.0±11.55	6.83±0.59	800.0±41.8	15.08±0.28	648.3±102.9	893.3±114.3	162.0±10.00
Control	3 to 4 months	57.5±0.28	72.5± 4.78	6.12±0.42	782.5±31.2	15.37±0.55	556.0± 33.1	791.2± 61.4	164.6±10.88
Calandrex		57.6±0.55	66.0± 5.10	6.70±0.26	785.0±27.2	16.32±0.87	492.5± 72.5	746.2± 67.4	152.0± 8.93
Carbon bisulfide		58.7±0.33	67.5± 4.34	6.61±0.24	817.5±18.9	16.25±0.42	525.0± 54.1	818.3± 59.3	156.5±14.14
Trichloroethylene		58.2±0.50	50.0± 4.08	6.88±0.24	807.5±17.9	15.68±0.29	565.3± 59.1	831.2± 48.7	167.7± 9.09
Carbon tetrachloride		57.7±0.74	52.5± 2.51	6.88±0.31	823.3± 6.8	15.31±0.23	596.3± 25.1	893.7± 21.6	172.2±11.98
Methyl bromide		58.6±0.26	55.0± 8.65	7.35±0.33	812.5±35.6	15.86±0.24	517.5± 46.0	777.5± 31.6	160.0± 7.26

^aMean and Standard Error.^bBased on three replicates only.

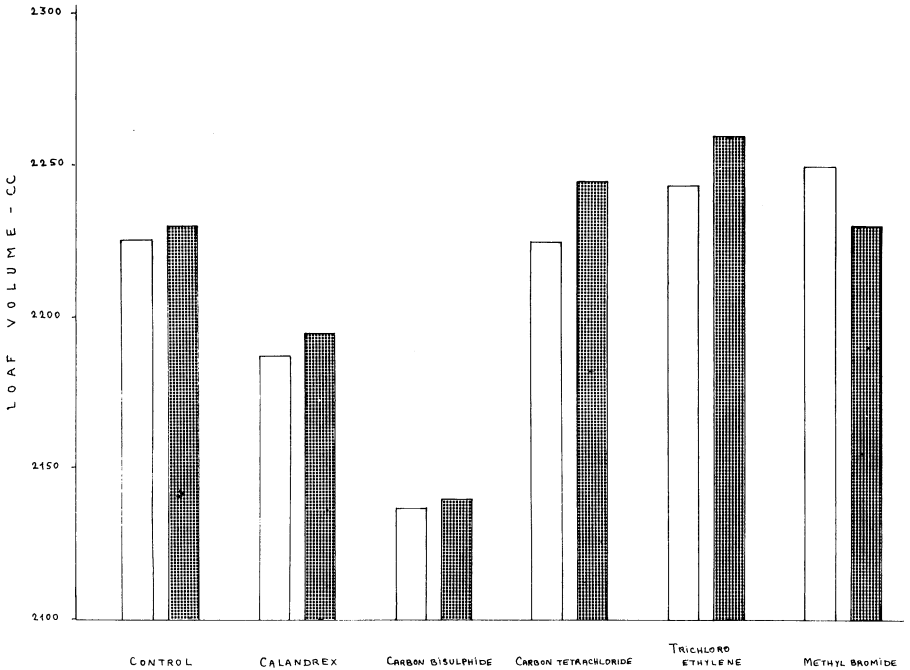


Fig. 2. Effect of fumigation with Calandrex, its components, and methyl bromide on the baking quality of wheat. Blank, 1 week after fumigation; cross-hatched, 3 to 4 months after fumigation.

5) Statistical analysis shows significant differences from control at the 5% level for carbon bisulfide.

Effect of Successive Fumigations

The effect of successive fumigations with Calandrex is clearly shown in Fig. 3. This effect was most detrimental after the third fumigation.

Successive fumigation with the liquid mixture carbon tetrachloride:methyl bromide did not result in lower loaf volume even after three fumigations in succession, as compared with untreated wheat.

DISCUSSION

As mentioned, studies on the effect of fumigants on the baking qualities of wheat are few. Among these, studies of the effect on grain are even more scarce. In the present work the common grain fumigants used in this country were tested.

At dosages similar to those used by Hermitte and Shellenberger (2), the baking quality of wheat treated with methyl bromide did not differ from that of the control. This is in agreement with the results of the above authors.

Data presented in the first series show clear differences between carbon bisulfide, the control, and the other fumigants tested in their effects on the baking qualities of wheat.

Dean and Swanson (1), who fumigated flour with carbon bisulfide at a rate of 1

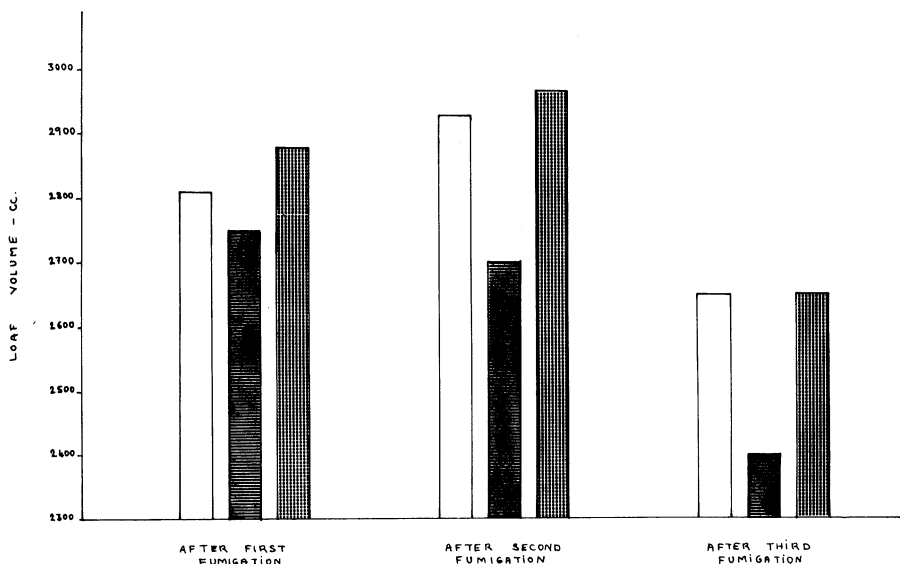


Fig. 3. Effect of three successive fumigations on the baking quality of wheat. Blank, control; horizontal lines, Calandrex; cross-hatched, carbon tetrachloride:methyl bromide (80:20).

lb. per 1,000 cu. ft. of space for 12 hr., did not find differences in baking qualities, apparently because of the lower concentration used.

Although in both series the effect of Calandrex on the baking quality of wheat was slight, if all replications of the two series are considered together, a 5% level of significance is obtained in comparison with the control. This detrimental effect caused by Calandrex may be attributed to the presence of carbon bisulfide in the mixture.

More research, however, is required to clarify the role of the factors involved, such as that of fumigant residues remaining in the treated grain.

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Literature Cited

1. DEAN, G. A., and SWANSON, C. O. Effect of common mill fumigants on the baking qualities of wheat flour. *Kansas Agr. Exp. Sta. Bull.* 178, p. 155 (1911).
2. HERMITTE, P. J. J., and SHELLENBERGER, J. A. Effect of excessive methyl bromide fumigation on flour. *Cereal Chem.* 24: 449 (1947).
3. BURNS BROWN, W., HESELTINE, H. K., DEVLIN, J. J., and GREER, E. N. The effect on flour of fumigation with methyl bromide. *Milling* 137: 401 (1961).
4. LARMOUR, R. K., and BERGSTEINSSON, H. N. The effect on wheat quality of long exposure to carbon tetrachloride. *Can. J. Research C* 16: 241 (1938).

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