Fumigating Stored Foodstuffs

R. T. Cotton

Fumigants can penetrate large bulks of stored foodstuffs and get at insects working far beneath the surface. They work fast and effectively against all stages of insects, even those concealed within kernels of grain. Their volatile nature insures the eventual disappearance of poisonous residues from fumigated foodstuffs. The cost of fumigation usually is low. The materials are inexpensive. Small dosages suffice. Little equipment is required to apply them. Fumigation is usually considered a curative measure, but it is essential in most programs for the prevention of insect damage to foodstuffs in storage. Fumigants are available to treat any type of foodstuff under almost any circumstance and for a long enough time to kill insects in the places where they are.

For those reasons, fumigants are more important in preserving stored foods from insect damage than any other agent or combination of agents. They have some drawbacks, however.

Some foodstuffs, notably those rich in oil, may retain obnoxious odors from certain fumigants and others may be adversely affected by repeated fumigations or excessive concentrations. The viability of seed may be reduced by some fumigants under certain conditions. If the commodities are in good condition, however, some fumigant or other can be relied on to do an efficient job without materially affecting them.

Grains, milled cereals, feeds, dried fruits, nut meats, dried meats, cheeses, powdered milk and egg, beans, peas, chickpeas, spices, coffee, and practically all dried foodstuffs can be safely and effectively fumigated.

For proper fumigation, one should know the fumigant or fumigants best adapted for treating each type of commodity under the varied conditions of storage he might encounter and the capabilities and limitations of the more important fumigants.

For successful fumigation the insect must be surrounded by the fumigant in a concentration heavy enough and for a sufficient time to produce death. Special techniques may be needed to tighten enclosures and insure the uniform distribution of the vapors. If enclosures cannot be made tight enough to hold fumigants, foodstuffs can be treated in bins, atmospheric vaults, barges, vacuum chambers, railroad cars, under tarpaulins, or in individual packages. With products such as grain in bulk it is possible to fumigate successfully large piles stored in loosely constructed buildings because of the ability of the grain to absorb and hold the vapors for considerable periods.

The infestation of grain by insects may start in the field or soon after it is placed in storage on the farm. As a preventive measure, it is wise to fumigate grain immediately after it is placed in storage in areas where field infestation occurs and within 6 weeks in all other areas.

The tendency of bulk grain to absorb fumigants makes it possible to treat grain successfully even though the bin in which it is stored is not airtight. The dosage of fumigant required will vary with the tightness of the bin and with the type of grain. Generally speaking, small grains require smaller dosages than corn since they retain the vapors for longer periods by their greater sorptive properties. On the other hand, the smaller size and still greater sorptive properties of grain sorghum obstruct the uniform diffusion of fumigants through the bin when they are applied to the surface, so that larger dosages are required for treating grain sorghum than for any other grain.

Low temperatures, layers of moist grain, and the presence of pockets of
dockage in bins of grain are factors that adversely affect the performance of grain fumigants. All these factors usually are considered in calculating the required dosages.

Many proprietary fumigants on the market differ slightly in composition from the compounds I have listed in the table. They may be used at the dosages recommended for the mixtures that they most closely approximate.

For best results in fumigating grain in farm bins, the surface of the grain should be level and at least 6 inches below the top of the side walls of the bin. Because strong winds and high temperatures accelerate the evaporation and loss of fumigant, applications should be made in the cool part of the day and when the air is quiet. In applying fumigants, the operator should cover the surface of the grain as uniformly as possible with a coarse spray. He should treat the grain from the outside of the bin to avoid exposure to the fumes. For small operations, a bucket pump or a knapsack sprayer can be used, but for larger operations a power sprayer is desirable. A pump with bronze fittings, which will not be affected by carbon tetrachloride or similar chemicals, and one that will pump the chemical directly from the drum is useful. In all operations a plastic-lined hose or one that will resist the action of carbon tetrachloride should be used. Washers should also be resistant to this and similar chemicals.

**Fumigation of Grain in Elevator Storage**

Fumigation of grain in elevator storage is much simpler than in farm bins, because elevator bins are usually much tighter and the uniform distribution of the fumigant is facilitated by its introduction into the grain stream as the grain is transferred from one bin to another.

Dosages of fumigants listed in the table, as modified for use in steel bins, can be used for treating grain in steel or concrete elevators. Besides these fumigants, calcium cyanide at 10 pounds and chloropicrin at 2 pounds per 1,000 bushels of grain can be used. In wooden-crib elevator bins, the dosage should be doubled. These dosages will give an excellent kill of adult insects but will seldom kill all the immature stages of weevils that breed within the kernels. Somewhat heavier dosages therefore should be used if the kill is to be complete.

Because many factors affect the efficiency of grain fumigants, the results are not always predictable. Grain that is high in moisture content, is cold, contains a lot of dockage, or has stood for a long time without turning is difficult to fumigate and may require much heavier dosages than normally are used.

Under average conditions the fumigant can best be applied to the grain

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**Fumigants and Dosages for the Treatment of Grain Stored in Wooden Farm Bins**

<table>
<thead>
<tr>
<th>Fumigant</th>
<th>Small grains except sorghums</th>
<th>Sorghums</th>
<th>Corn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon tetrachloride</td>
<td>Gallons 5</td>
<td>Gallons 8</td>
<td>Gallons 6</td>
</tr>
<tr>
<td>Carbon tetrachloride:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 parts + carbon disulfide 1 part</td>
<td>3</td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td>1 part + ethylene dichloride 3 parts 2</td>
<td>6</td>
<td>10</td>
<td>6</td>
</tr>
<tr>
<td>19 parts + ethylene dibromide 1 part</td>
<td>3</td>
<td>8</td>
<td>6</td>
</tr>
</tbody>
</table>

1 In steel bins the dosages may be reduced 50 percent for small grains and about 20 percent for corn and grain sorghum.
2 The addition of 5 percent by volume of ethylene dibromide improves the kill of immature stages of insects in grain.
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stream while the bin is being filled. Special applicators designed to feed the fumigant into the grain stream at the desired rate are used for chloropicrin or calcium cyanide. Other fumigants are poured into the grain stream at regular intervals by hand or may be applied with an automatic applicator adjusted to operate continuously when the grain is running. When grain cannot be turned, the fumigants other than chloropicrin or calcium cyanide can be applied by spraying the entire dosage uniformly over the top layer. If grain temperatures are above 80°F., the vapors will penetrate the mass of grain to the bottom of the bin.

For control of surface infestation by the Indian-meal moth or the almond moth, the various bin openings (ventilators, manhole covers, loading chutes) should be closed and scaled and a fumigant applied as a fine spray or vapor. The aim is to retain the fumigant at the top of the bin rather than have it sink down through the mass of the grain. Chloropicrin alone can be applied by means of a garden sprayer to the space above the grain in closed-top bins at the rate of 1.5 to 2 pounds per 1,000 cubic feet of space above the grain. Mixtures of 80 percent methyl bromide and 20 percent chloropicrin, or 80 percent methyl bromide and 20 percent ethylene dibromide likewise can be applied at the rate of 1.5 pounds per 1,000 cubic feet of space above the grain.

Some grain-elevator bins in Europe and North Africa are equipped for circulating a gas within the bins during and immediately after its introduction. Although the method has not been adopted for elevator bins in the United States, it has been successfully used in the fumigation of grain in steel tanks of 350,000-bushel capacity in Texas.

Blowers introduce the fumigant into the top of the bin and pull it down through the grain and out through ducts to the blower again so that it can be recirculated. This method gives a uniform distribution of the fumigant within 30 minutes, and the fumigant can be removed and replaced with fresh air after the fumigation. Methyl bromide can be used successfully by this method at dosages so low that fumigation costs are extremely reasonable. For grain sorghum a dosage of 3 pounds of methyl bromide per 1,000 bushels of grain gives excellent results.

For the temporary storage of large stocks of surplus grain, Quonset huts, airplane hangars, barracks, and warehouses of all kinds are used. The grain is usually stored in a pile on the floor and seldom completely fills the structure. The buildings usually are not tight, and the problems of storage are complicated.

Piles of grain in such storages can be successfully treated with fumigants sprayed over the surface of the pile, even though the buildings are not tight. The grain mass holds the fumigant so well that excellent kills can be obtained. During cool weather, insect colonies tend to bunch together near the center of such piles. Such infestations are eliminated by spot applications of fumigants. The area of infestation can be determined by taking probe samples. The fumigant should be applied directly over the infested area, so that it covers a few feet beyond the limits of the infestation.

In both corn and wheat, dosages of 4 to 5 gallons of 4 parts of carbon tetrachloride and 1 of carbon disulfide per 1,000 bushels have given excellent results in spot treatments or in the fumigation of the entire pile.

The fumigant can be applied with a power sprayer that delivers the liquid rapidly as a coarse spray. Many Quonsets have roof hatches, through which the fumigant can be applied; if not, the operators can enter the building and spray the fumigant uniformly over the pile, starting from the rear and working towards the exit.

Adequate hose and a pump capable of throwing a stream about 75 feet at the rate of 100 gallons a minute should be used.

During manufacture and processing and subsequent storage in ware-
houses, dried foods are exposed to infestation by insects that become established in the machinery or in various parts of the mill, manufacturing plant, or warehouse. A planned program of fumigation can do much to prevent such infestation.

In former years a general fumigation once or twice a year with hydrocyanic acid, methyl bromide, or chloropicrin was relied on to keep premises free from insects. Modern demands for food entirely free from insect infestation have caused the adoption in many plants of a biweekly program of local fumigation, whereby individual milling units or food-handling machines are fumigated and the fumigated stock removed by heavy-duty vacuum cleaners. In some mills the biweekly application of local fumigants takes the place of a general fumigation. Local fumigants, if regularly used, will maintain a low insect population in milling machinery but cannot be expected to destroy infestations in all parts of the plant, so that an occasional general fumigation is helpful.

General fumigants are usually introduced into the open space of the building, but sometimes are also introduced through piping systems directly into the machinery.

Local fumigants may be applied by hand by pouring them into the individual milling units or machines. Liquid fumigants may also be applied with permanently installed dispensers. Portable fumigant dispensing tanks are used to force the fumigant into fabric tubes installed permanently inside conveyors or other units. A fully automatic system dispenses the fumigant in vapor form from a central supply connected by tubing to individual milling units.

Chloropicrin, hydrocyanic acid, and mixtures of carbon tetrachloride with ethylene dibromide, ethylene dichloride or other chemicals are used extensively as local fumigants.

For the fumigation of warehouses filled with grain, feed, flour, or other dried foodstuffs, methyl bromide or mixtures of methyl bromide with chloropicrin or ethylene dibromide have been found most effective. Perfect penetration of large stacks of bagged materials can be obtained with dosages of 1.5 pounds per 1,000 cubic feet of space. To obtain uniform distribution of the fumigant and to prevent stratification of the vapors near the floor, electric fans should be operated for 1 hour after release of the gas.

The use of tarpaulins or gas-proofed fabrics in the fumigation of stored foodstuffs sometimes may be more convenient than fumigating in large, partly filled warehouses or in atmospheric vaults. The tarpaulin, which takes the place of the fumigation chamber, is portable and occupies little space when not in use. The free air space is reduced to a minimum and aeration is facilitated by the complete removal of the tarpaulin from the stack of commodities after fumigation. The products to be fumigated are generally stacked on a concrete floor and covered completely by the tarpaulin, the edges of which are weighted down carefully to prevent leakage of gas around the base. Provision is made for an air dome at the top by using two sacks placed edgewise about 4 feet apart. The air dome will provide free air space to permit diffusion of the gas.

A rubberized fabric or a light duck material coated with ethyl cellulose usually is used. Any fumigant suitable for the treatment of bulk commodities in atmospheric vaults or warehouses can be used to treat foodstuffs under tarpaulins.

Atmospheric vaults are useful for the fumigation of foodstuffs when warehouses are not tight enough for efficient fumigation or when small lots—incoming raw materials, returned goods, used bags, and out-going products of all kinds—need treatment. Many different materials can be used to construct atmospheric vaults, but a metal vault or one with a metal lining is most efficient. Tubing and spray nozzles for introducing volatile fumigants and fans for circulating the
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fumigant or exhausting the vapors are necessary.

The actual process of fumigation is simple. The commodity is loaded into the vault by hand or run in on trucks or skids. The door is closed and the fumigant introduced. At the end of the fumigation, the exhaust fan is turned on and allowed to run until the vapors, not absorbed by the fumigated commodity, have been removed. While the vault is being unloaded, the exhaust fan should be kept running. Sometimes auxiliary fans may be needed to supply fresh air for the workmen unless they wear gas masks.

Methyl bromide and mixtures of methyl bromide with chloropicrin or ethylene dibromide are most efficient for use in treating dried foodstuffs in atmospheric vaults, although hydrocyanic acid, chloropicrin, and many other fumigants can be used. Dosages depend on the commodity to be fumigated, the quantity involved, and the fumigant.

Fumigation by vacuum consists of placing the commodity in a gas-tight steel chamber, removing the air, and replacing it with a gas lethal to insects. By this method a more rapid penetration of commodities by the gas is obtained than in atmospheric fumigation, and insects are reached and killed faster than in an atmospheric vault. The removal of a large part of the oxygen from the chamber makes the insects more susceptible to fumigants. The length of exposure ranges from 1 to 3 hours, compared to 10 to 24 hours under atmospheric conditions—an important factor in industries where speed is essential in handling foodstuffs.

Vacuum fumigation has several other advantages. At the end of a fumigation, the removal of the fumigant from the treated commodities can be speeded up by a process known as air washing. It consists of drawing a vacuum of 27 inches or more and breaking it with air. There is little danger that workmen will enter a vault undergoing fumigation, and the danger from breathing the vapors during the unloading of a vault is lessened.

It is advantageous to draw as high a vacuum as possible and to hold the vacuum throughout the exposure. By circulating the gas in the tank for 15 minutes after it is introduced, the distribution of the fumigant will be aided greatly, and much less fumigant will be needed to effect a kill than if the gas is not circulated.

The fumigants usually employed in vacuum vaults are methyl bromide, hydrocyanic acid, and a 1-9 mixture of ethylene oxide and carbon dioxide.

Dosages vary with the fumigant, the commodity, and the length of the exposure. The shorter the exposure, the larger the amount of the fumigant required.

The fumigation of individual packages of foodstuffs is practiced in some food industries, but is expensive because comparatively large quantities of fumigant must be used. In this method, the individual packages traveling along a belt pass under an applicator, which automatically injects a certain amount of fumigant into each one. The packages are then sealed. Each package is its own fumigation chamber. The method was first used extensively in the United States to treat packages of dried fruit, for which ethyl formate, methyl formate, and isopropyl formate have been used. Other products so fumigated are dried soupstocks, rice, dog biscuits, popcorn, and such. Besides the formates, acrylonitrile in admixture with carbon tetrachloride has been used for individual packages.

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