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Review and prospect for development of food grain fumigation machineries in India

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ABSTRACT

The objective of this study was to review the development history of food grain fumigation machinery in India. The study described the present situation of food grain fumigation machinery for the warehouses and silos and the development of future food grain fumigation technology. Double-recycling fumigation and aeration system, and side combing circulating fumigation system can be used for warehouse. Grain fumigation machinery in grain silos includes circulating fumigation system equipment in large grain silos and automatic phosphine pellet dispenser. These fumigation machineries include air inlet box, air outlet box, recycling pipes, fan, plastic film cover on food grain pile, monitor measurement for grain temperature and control system, PH_3 generator, manual AlP dispenser, air direction transfer, gas sampler and moving vehicle. India is going into 21st century, the science and technology are forging ahead and will bring about changes day after day. Grain fumigation machinery in silos developed towards new and high technology. General developing trend of Indian food grain industry is toward two poles— one is food grain distribution system with high speed, large capacity, unobstructed fast and convenience and another is more stable grain reservation.

Key words: Aeration, Double-recycling fumigation, Fumigation machinery, Food grain storage, Pellet dispenser

Estimated Indian food grain output for 2014-15 has been indicated as 257.1 million tonnes (238.6 million tonnes of cereal grains and 18.43 million tonnes of pulses) (Table 1). About one-third of wheat (*Triticum aestivum* L.) and rice (*Oryza sativa* L.) produced is procured by central and state grain storage agencies for the central pool for public distribution throughout the year and as a reserve stock towards food security. Though pulses come under the category of food grains as per IS 2813:1995, their storage period is short, they are never held as buffer stock and are consumed domestically and India generally imports pulses (4.6 million tonnes in 2014–15) to meet the domestic demand. Grain procured is stored mainly as 50 kg bags and bag-stacks are held in conventional warehouses or godowns (total covered storage capacity about 72.4 million tonnes as of 2014) of the Food Corporation of India (13.0 million tonnes), the predominant storage agency responsible for maintenance of buffer and operational stocks and supporting agencies such as the Central Warehousing Corporation (8.68 million tonnes), state warehousing corporations (25.57 million tonnes), cooperative sectors (15.34 million tonnes) and state civil supplies corporations (9.8 million tonnes). As there is a shortage for permanent storage structures, about 15.7 million tonnes of food grains (wheat and rice) have been stored temporarily outdoors as Cover and Plinth (CAP) storage (Rajendran, 2016).

Table 1. Production of food grains in India

Commodities	Production in million tonnes	
	2013–14	2014–15
Rice	106.65	103.04
Wheat	95.85	95.76
Maize	24.26	22.97
Pearl millet	9.25	7.91
Sorghum	5.54	4.83
Finger millet	1.98	1.89
Barley	1.83	1.77
Other millets	0.43	0.46
Total	245.79	238.63

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Table 2 Fumigants approved by the Registration Committee under the Insecticides Act, 1968

Fumigant	Formulations	Comments
Aluminium phosphide	56% 3 g Tablets*; 56% Powder*, 15% 12 g Tablets, 6% Tablets	General purpose fumigant for various stored products (6% tablets used for rodent burrow fumigation)
	10g Pouches	Used at farm level
	77.5% Granules	Used in on-site phosphine generators
Methyl bromide*	99% Technical,	For quarantine and pre-shipment
	98% with 2% Chloropicrin (w/w)	(QPS) use only
Ethylene dichloride and Carbon tetrachloride	3:1 mixture (v/v)	Used for small-scale/ farm level fumigation

*Restricted use, i.e. to be used by Govt. approved agencies under expert supervision only. Other registered fumigants in India include 56% magnesium phosphide plates (for export tobacco fumigation) and 96% sodium cyanide (for cotton bale treatments).

Food grains held in both temporary and permanent storage structures, indoors or outdoors, are vulnerable to insect infestation. Insect pest activity is generally high due to favourable climatic conditions, i.e. >25°C and >50% r.h., in the country and infestation problem is acute in storage centres located in coastal region. Type of pests attacking food grains varies according to commodity and climatic conditions (Table 2). The rust red beetle, *Tribolium castaneum* (Herbst) is common but occurs more in milled rice than in rice. Khapra beetle infestation is restricted to extreme climatic regions, viz. Punjab, Haryana, Bihar and Uttar Pradesh. Notorious pests such as *Prostephanus truncatus*, the larger grain borer and *Plodia interpunctella,* the Indian meal moth have been noticed in some of Indian grain storage centres (Bell, 2000).

As mixing of residual insecticides with food grains is not permitted in India from the beginning, we are greatly dependent on fumigants in the preservation of food grains. Supplementary control measures in grain storage premises include space sprays (fogging and misting) and hard surface sprays with contact insecticides such as deltamethrin, malathion and pirimiphos methyl (Rajendran and Sriranjini, 2008).

There is a very important problem related to the needs of peoples lives and improvement of living standard that makes grain production, storage, processing and sales fast development. Application of fumigants to kill insects in stored grain. It is the most effective way to ensure safe storage and decrease losses of stored grain. The use of fumigants has been done in India for several decades, but the development of grain fumigation machinery is just a new thing in recent years. With the continued development in Indian grain industry, grain fumigation machinery has made great progress. It is playing the increasingly important role in foundation and perfection of Indian grain distribution system, keeping grain quality, decreasing grain loss and raising grain distribution efficiency (Anon, 2016).

DEVELOPMENT AND APPLICATION OF CHEMICAL FUMIGANTS

The history of applying chemical fumigants to prevent and kill insects in stored grain has been several decades or more than 100 years. Carbon disulfide (CS_2) was first applied to grain fumigation in France in 1854. Chloropicrin and methyl bromide were used in France in 1917 and 1932. Hydrogen phosphide (PH_3) began to be used in Germany in 1935. The principle of fumigation is that poisonous steam produced by easy-evaporate chemical fumigants are mixed in air and reaches a certain concentration. This gas enters the insect's body through respiratory system or insect cuticle. After sometime, the insects are poisoned to death. At present, fumigants widely used in India are mainly hydrogen phosphide, methyl bromide, chloropicrin, ethylene oxide, carbon disulfide, etc. Methyl bromide began to be produced in China in 1954 and was applied for grain fumigation in 1955. Pellets of aluminium phosphide (AlP) were developed in 1963. The pellet and powder of AlP were widely used in grain industry. Now AlP is the fumigant more used and produced in India (Anon, 2009).

At present, there are only four registered fumigants in India (Table 2). However, for treating food grains, phosphine (AlP solid and powder formulations) and ethylene dichloride- carbon tetrachloride (EDCT QPS) mixture have been approved. Methyl bromide is allowed only for quarantine and preshipment (Anon, 2011).

PRESENT SITUATION OF GRAIN FUMIGATION MACHINERY IN WAREHOUSES

Warehouse are about 80% of total grain storage in India, most of which are used for reservation. Because of poor seal, less machinery's and insufficient technical

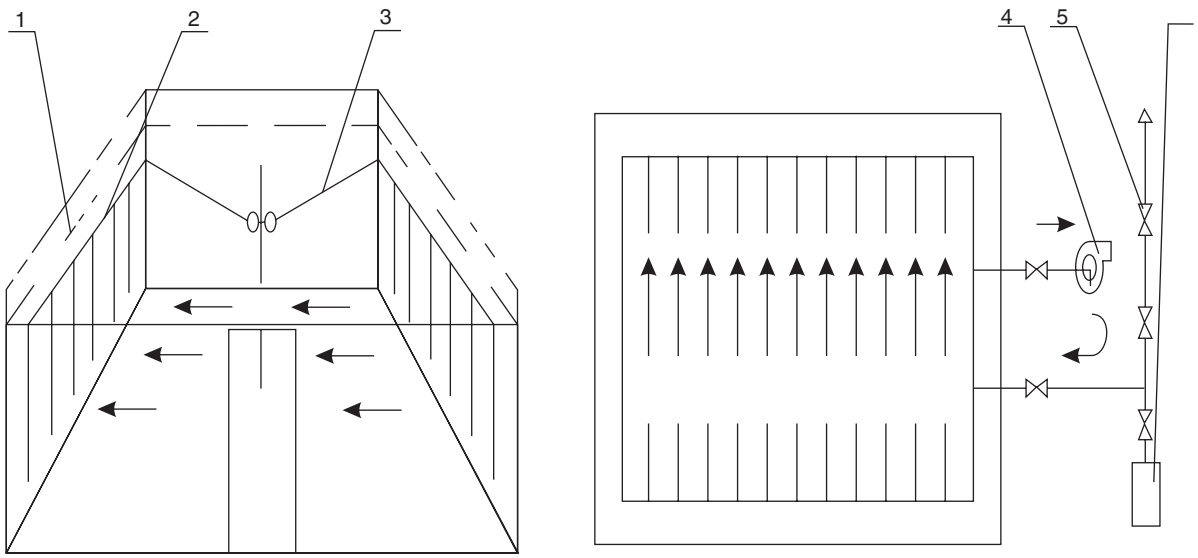

Fig. 1. Double-recycling fumigation and aeration system (1, grain surface; 2, outlet networks; 3, inlet pipe networks; 4, fan; 5, sealing valves; 6, PH_3 generator)

knowledge of labours, fumigation used before was mainly manual operation in warehouses. There were many difficulties for fumigation in flat warehouses, so that the development of fumigation machinery was very slow. The fumigation machinery having better effect includes side combing circulating fumigation system used for flat warehouse and double-recycling fumigation and aeration system (Ababa, 2004).

Double-recycling fumigation and aeration system

Double-recycling fumigation and aeration system was developed on the basis of thin plastic film cover (Fig 1). It namely consists of air inlet box, air outlet box, recycling pipes, fan, plastic film cover on grain pile, monitor instrument for grain temperature and control system. For inside recycling system, air blown by fan pushed fumigation gas into grain pile, then passed through the recycling pipe and entered fan inlet again. After 2–3 times of circle, fumigation gas is evenly distributed inside the grain pile. Switch off fan and seal the grain pile to get a goal of killing insects in grain pile. For outside recycling system, suitable dry and cool air is drawn into grain pile through air inlet box. Then the air absorbing heat and damp is removed from grain pile through outlet box by this means, the aim to drop the temperature and moisture content of stored grain is achieved. The practice for many years has proved that, double-recycling fumigation and aeration system has good effect for killing insects in grain pile and for ventilation to drop temperature and

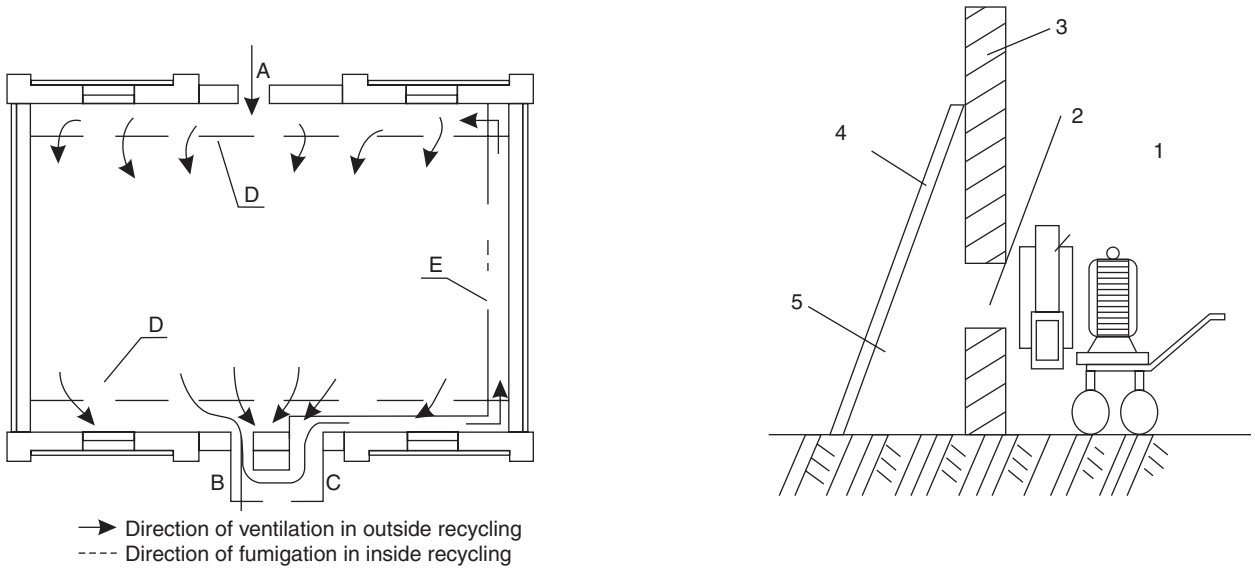

Fig. 2. Side combing circulating fumigation system. A, Inlet; B, outlet; C, inlet of recycling pipe; 1, fan; 2, connecting pipe; 3, wall; 4, porous board; 5, mangle gas box

moisture content of stored grain. It has the good benefit in saving manpower and energy. It is a big progress for grain storage technology in warehouse (Lailin, 1994).

Side combing circulating fumigation system used in warehouse

It consists of two parts— main equipment and pipe networks. Main equipment includes fan, PH_3 generator, manual AlP dispenser, air direction transfer, gas sampler and moving vehicle. Pipe network comprises inlet pipe network, outlet networks and sealing valves. Sealed grain pile is also a component of the system. Inlet and outlet networks are formed by connecting steel pipes installed in equal distance on both inside of flat warehouse. The pipes must be located under the surface of grain pile. The pipes are sealed at one end, and there are many small holes on pipes. The form of installed system is like a comb. Pipe networks are guided out of warehouse and connected with main equipment by ball valve (Liu, 1997). The flowchart and connection of whole system is shown in Fig. 2.

GRAIN FUMIGATION MACHINERY IN GRAIN SILOS

Grain is usually stored in piles very high, so that natural diffusion of the fumigant gas is very slow and cannot evenly spread in the grain pile. Control of insects in grain silos had been very difficult for a long time. Only after a variety of special fumigation machines were developed, fumigation in grain silos and safe storage of grain may be guaranteed (Renkang, 1992). They all showed very good results in killing insects in grain silos.

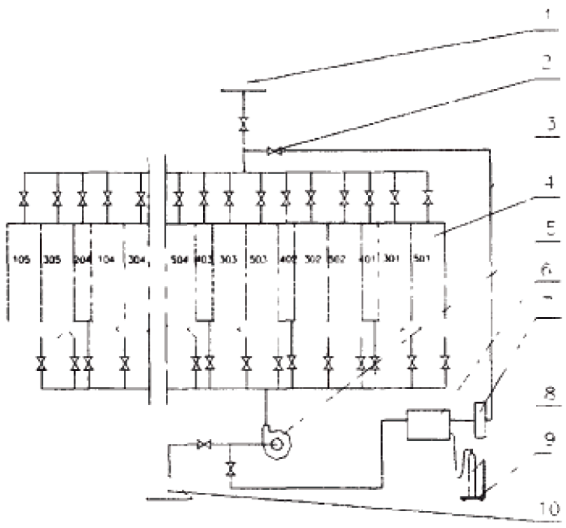

Fig. 3. Circulation fumigation equipment for large grain silos. l, Gas outlet; 2, valves; 3, recycling pipe; 4, silos; 5, gastight fan; 6, vapourizer; 7, dust remover; 8, fumigant; 9, scale; 10, air inlet

Circulating fumigation system equipment in large grain silos

Circulating fumigation equipment for large grain silos consists of vapourizer, valves, airtight fan, recycling pipe, dust remover, air inlet and outlet (Tan, 1992). The working principle of the equipment is as follows: vapourizer, valves, air-tight type fan, recycling pipe, dust remover, and air inlet outlet, and silo are connected together to form a close recycling circuit (Fig 3). Before fumigation, open all valves on recycling circuit formed with silo 501 and close others. Switch on the fan and open the valve of fumigant bottle. Fumigant (methyl bromide, PH_3 or carbon dioxide, etc.) was introduced into vapourizer to form fumigation gas and was blown into grain pile from the bottom of silo. Fumigant gas went up along whole section of silo through grain pile and escaped out of grain surface by the action of fan, the gas containing fumigant returned to the inlet of fan again through recycling pipe and dust remover. Thus, a circle was ended. A scale measured the amount of fumigant applied. While the given amount was reached, the valve of fumigant bottle was closed after several cycles, fumigant gas was evenly spread in grain pile. Switch off the fan, close upper and lower valves of silo 501 and keep silo 501 to be sealed. Then, open upper and lower valves of silo 301, start fan, measure the amount of fumigant applied, close valves and seal the silo. Fumigation was carried out silo by silo, until all silos to be fumigate were fumigated. After

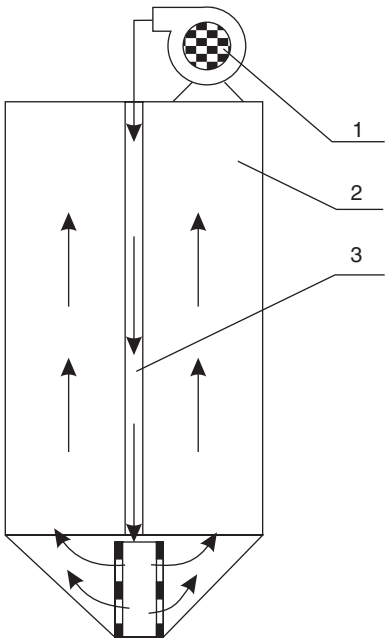

Fig. 4. Multi-function aeration and fumigation system. 1, Fumigation fan; 2, silo; 3, multi-function aeration and fumigation apparatus

being sealed for 48 h, open upper and lower valves of silo 501, start fan, open inlet and outlet valves of fumigation equipment and exhaust fumigant gas in silo and recycling pipe out of silo. Silo 501 was ventilated for 2 h. Next, close upper and lower valves of silo 501, open upper and lower valves of silo 301. Then the silo 301 is also ventilated in 2 h. Fumigation and ventilation were earned out as mentioned above silo by silo. After the last fumigated silo was ventilated, fumigation was finished (Wenge, 1996).

Automatic phosphine pellet dispenser

It is a new fumigation machine used in grain silos. The machine is mainly comprised pill container, mechanism for putting in order and numeral delivering system (Yaoxi, 1984). This machine is installed at proper place on the intake conveyer on top of grain silos. When entering grain, pills will automatically go out from the machine according to given dosage, fall in the conveyer and enter in silo along the grain stream silo is sealed after loading grain. AlP pills absorb damp in grain pile and produce phosphine gas. Fumigation will be finished after one month. Then open the ventilation hole on top of silo to pull out exhaust gas when concentration of PH_3 in silo is lower than a given value (0.05 ppm), the stored grain may be taken out (Fig 4).

Automatic AlP pellet dispenser used for silo fumigation has more advantages: simple equipment, convenient use and less investment. Its drawback is longer fumigation time. If it is used in coordination with fan, fumigation time will be shortened (Zhang, 1996).

DEVELOPMENT TREND OF GRAIN FUMIGATION MACHINERY IN THE FUTURE

Science and technology are forging ahead and will bring about changes day after day. Grain fumigation machinery also developed towards new and high technology. General developing trend of Indian grain industry is towards two poles. One is grain distribution system with high speed, large capacity, unobstructed fast and convenience. Another is more stable grain reservation. In order to fit the need of these trends, the development of grain fumigation machinery should pay attention on following points:

- To construct fast fumigation facility with good air tightness at grain terminals and transfer depots with large throughput. This facility should be used in both silos and squats. Once insect damage happens, fumigation can be done in time to prevent infection by insects, especially quarantine insects. It will not only ensure safety of agricultural products, but also keep high operation efficiency of grain distribution system.
- Low dosage fumigation method can be used for flat warehouse and reservation warehouse with normal air tightness. This technique combined with controlled atmosphere (to reduce the content of oxygen and addition of carbon dioxide) will restrain the activity, reproduction and spread up to kill insects and keep grain quality.
- For long term stored grain, protectants may be used to prevent insect infection.
- Some controlled atmosphere warehouse should be built. They will apply the technique of removing oxygen by filling nitrogen or carbon dioxide to control active growth of insects and mold. This technique will not only keep grain quality, but also reduce the amount of fumigant applied, which is very beneficial for environment protection.

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