Protection of Stored Products with Special Reference to Thailand*

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Abstract

Stored products include materials, which may be dried, rendering them storable for future use as food, industrial raw materials, medicines, or as planting materials. These include cereals, pulses, dried seeds and root crops. Insect infestation is a major contributor to quality deterioration of stored products kept in warm and humid climates. Considerable physical and nutritional loss sustained are due to infestation of stored food products by weevils, bruchids and other insects. Apart from the detrimental economic impact, these losses pose a major threat to food security. Traditional methods of applying spices, medicinal plants and their extractives, and inert materials with pest control potential as storage protectants, have increasingly been explored and exploited in the developing world as alternatives for the control of pests of stored products. In addition to insects, several other organisms attack stored products. These include microorganisms (mainly fungi and bacteria, which cause infection and deterioration), mites, rodents and birds. Plants and plant products can affect insects and other storage pests in various ways by exhibiting pest control activities as toxicants, attractants, repellents, antifeedants and growth regulators; they are also effective as antimicrobials and antifungals. Several kinds of materials are used as a means of stored food protection, including chemical fumigation, treatment with synthetic pesticides, and inert materials. This paper will review research relevant to the application of botanical pesticides, particularly those derived from spices and medicinal plants, and also inert materials, which are traditionally applied to control stored food pests in Thailand.

Keywords: Stored products, stored pests, insect infestation, weevils, bruchids, storage protectants, toxicants, attractants, repellents, antifeedants, growth regulator, antimicrobials, antifungals, chemical fumigation, synthetic pesticides.

Introduction

Insect infestation is a major contributor to quality deterioration of durables (cereals, pulses, roots and tubers) stored in warm and humid climates. Considerable physical and nutritional loss sustained in these countries are due to infestation of stored food products by weevils, bruchids and other insects. Apart from the detrimental economic impact, these losses pose a major threat to food security. Currently, insect control in stored products relies primarily upon the use of gaseous, synthetic fumigants and residual insecticides, both of which may pose serious hazards to warm-blooded animals and the environment. Residues of methyl bromide, one of the two synthetic fumigants still used in the disinfection of stored foods, have been found to exhibit carcinogenic effects in rats (Dansi et al. 1984). The other fumigant, phosphine, is becoming ineffective as a stored food protectant, since insects are beginning to exhibit resistance to this insecticide (Tyler et al. 1983).
A revised version of a part of the consultant report on “The Use of Traditional Protectants in Stored Product Protection”, submitted by the author to FAO, Rome, Italy.

Disinfestation technologies such as controlled, or modified-atmosphere storage, the application of contact insecticides, and biological and physical control methodologies are being increasingly applied in the developed world as a follow-up to the ruling of the Montreal Protocol for the phasing-out of the use of methyl bromide. Applicability of these disinfestation techniques in a majority of developing countries is however, limited by cost and socio-economic factors. Thus, the traditional methods of applying spices, medicinal plants and their extractives, and inert materials (sand, charcoal and ash) with pest control potential as storage protectants, have increasingly been explored and exploited in the developing world as alternatives for the control of pests of stored products. Golob and Webly (1980) made an excellent review on the use of botanicals and minerals to control storage pests.

In addition to insects, several other organisms attack stored products. These include microorganisms (mainly fungi and bacteria, which cause infection and deterioration), mites, rodents and birds.

In most developing countries, the major portion of stored foods is kept on-farms, although a significant portion is also transported for storage in households. A very small percentage is stored in community or commercial storage facilities where modern technology such as the use of chemical fumigants, is employed in stored food protection. Qualitative and quantitative losses of stored products that occur due to physical, biological, chemical and engineering factors greatly affect the amount and quality of foods produced. Prevention of food loss with the concept of, “a grain saved is a grain produced” should be taken seriously into consideration by all concerned, since productivity gains in food production are misleading if measured at the point of harvest, rather than at the point of consumption. Therefore, there is an urgent need for technologists and scientists to develop simple and economical codes of practice, which can be implemented to minimize any avoidable wastage of stored products, both on farms and at the farmer storage level.

This paper focuses on the current status of the application of traditional materials (spices, medicinal plants, their extractives, and inert materials) in stored food protection at farm, domestic, and commercial levels in Thailand.

Storage Facilities

Storage Levels

Storage levels are of three types, namely (i) farmer storage, (ii) community storage, and (iii) commercial storage:

Farmer Storage: This is made up of locally available materials. The produce is stored in heaps on the ground for periods varying from a few days to a month or more after which it is transferred to temporary structures. Cereals such as maize or sorghum are not threshed but cobs are stored in heaps in wooden racks or hung on ropes under a shed. The prevailing high humidity during the harvesting of these crops is perhaps the main reason for open storage. Paddy, wheat, pulses and seeds are stored in bulk in close structures. The advantages of bulk storage are greater storage capacity per unit volume of space, minimal difficulty in loading and unloading, and availability of gunny bags at no cost. Bag storage is used, because each bag is a definite unit and can be handled easily for marketing and fumigation, and proper stacking can eliminate the problem of sweating.

Several types of farmer storage structures are utilized in different countries. These include underground cellars, mud bins, straw bins, wooden bins, bamboo bins,
cement bins, etc. Storage facilities may be located on farms, i.e. at the site of harvest, or adjacent to the houses of the farmers. Since most farmers are poor and the amount of produce to be stored is small, rodenticides or other pesticides are not applied in storage.

A large proportion of harvested food grains is normally retained at farmers’ level in traditional storage structures. Singh (1993) gave an estimate of such amount to be 60-70%, while Semple (1990) gave higher figures of 70-90% stored for six months to a year at farmers’ level. In traditional storage structures made of locally available materials such as paddy straw, split bamboo, reeds, mud, bricks, etc., which are not insect proof. Most farmers are using traditional methods, which include the use of botanicals and other inert materials for the control of storage pests. They can be used economically to achieve acceptable levels of pest control in villages and remote areas in developing countries.

**Community Storage:** These are storage facilities owned by farmers’ cooperatives, farmer groups, or any other types of community establishments such as the ‘Rice Bank’ and ‘Seed Bank’ in Thailand, where produces are stored in bulk or in bags in such facilities temporarily. Some facilities are also equipped with fumigating capabilities. Very few, however, utilize traditional methods of storage pest control, mainly because of the difficulty in applying botanicals or inert materials in large areas.

**Commercial Storage:** These are storage facilities owned by middlemen, millers, exporters, or manufacturers (of certain industrial products) for their own commercial benefit. Generally speaking, this type of storage is more modern than the first two types such as having better construction materials and layout, with fumigation facilities. The capacity is also much larger than the first two types. The use of broad-spectrum synthetic pesticides has been popularized and practiced in commercial storage facilities. In addition, the use of carbon dioxide fumigation has also been adopted in large warehouses, especially those stacked with bagged rice, as it is very effective in controlling stored insect pests, economic, and has advantage over the conventional fumigation.

**Storage Places**

These are facilities used to store products, which can be any one of the following:

- **Containers:** These may be gunnysacks, plastic bags, glass jars, or any type of containers.
- **Open Spaces:** This may be a drying floor, or any open space near the house, etc.
- **Shelves:** These are any shelves in the house or barn, which can be used to place products for storage.
- **Underground Storage Chambers:** These are chambers built underground either to save space or for other reasons, e.g. lower temperatures, ease in protection against rodents and birds, etc.

**Stored Products**

Stored products include any materials, which may be dried, rendering them storable for future use as: foodstuffs, industrial raw materials, medicines, or as planting materials. These include cereals, pulses, dried seeds and root crops.

**Cereals**

These are grains obtained from the grass family Poaceae, including rice, wheat, maize, millets (several species), sorghum, barley, oat, rye, Job’s tear, etc.

**Pulses**

These are dry food legumes, which include oil seeds (soybean and groundnut), and pulses (mungbean, blackgram, cowpea, pigeon pea, kidney bean, rice bean, lentil,
lablab, chickpea, lathyrus, etc.), all of which are classified under the Leguminosae family.

Dried Seeds of Other Plants

These are the seeds of certain plants, which are used for specific purposes. They include coffee seeds, seed spices (pepper, cardamom, coriander seed), other non-leguminous oil seeds (sunflower, safflower, sesame), lotus seeds, etc.

Root Crops

These are underground storage organs of plants (root, tuber, rhizome, bulb, corm, etc.) including potato, sweet potato, yam, cassava, onion, garlic, ginger, galangal, etc.

Miscellaneous

These include any materials generally stored on farms, such as: tobacco leaves, other dried leaves, copra, cinnamon bark, dried fruits, dried chilies, cacao, flour, sugar, animal feed, cereal products, leather, rubber, tapioca, etc.

Storage Pests

Storage pests can be grouped under the following categories:

Invertebrate Pests

Invertebrate pests include insects, microorganisms, and miscellaneous invertebrates.

Insects: Insects are the most important group of pests attacking stored food, including cereals (paddy and milled rice, maize, wheat, millets, job’s tear); shelled and unshelled pulses (e.g. mungbean, blackgram, soybeans, groundnut, kidney bean, lablab, chickpea, lathyrus, etc.). And, other dried products such as: coffee, pepper, chilies, cardamom, coriander seed, etc.

Nearly one thousand species of insects have been found associated with stored products in various parts of the world. The majority of the insect pests belong to the orders Coleoptera and Lepidoptera, which account for about 60 and 8-9%, respectively, of the total number of species of stored product insect pests. A list of important insect pests of stored products is given in Table 1.

In addition to causing damage and loss of stored products, insect pests may also pose health risks, causing allergic reactions and skin irritations through contamination of food products (Reuter and Bahr 1988). The Tribolium species produce a mixture of quinones, which have been shown to induce cancer in test animals (El-Mofty et al. 1989).

Table 1. Important insect pests of stored products

<table>
<thead>
<tr>
<th>Species</th>
<th>Common name</th>
<th>Stored products attacked</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Acarus siro</em></td>
<td>flour mite</td>
<td>cereals, cereal products, dried fruits, tobacco</td>
</tr>
<tr>
<td><em>Acanthocelides sp.</em></td>
<td>pulse weevil</td>
<td>many pulses including kidney bean</td>
</tr>
<tr>
<td><em>Callosobruchus analis</em></td>
<td>cowpea weevil</td>
<td>many pulses</td>
</tr>
<tr>
<td><em>Callosobruchus chinensis</em></td>
<td>cowpea weevil, Southern cowpea beetle</td>
<td>many pulses including soybean except kidney bean</td>
</tr>
<tr>
<td><em>Callosobruchus maculatus</em></td>
<td>cowpea weevil, pulse beetle</td>
<td>many pulses except soybean except kidney bean</td>
</tr>
<tr>
<td><em>Carpophilus hemipterus</em></td>
<td>dried fruit beetle</td>
<td>dried fruits, groundnut</td>
</tr>
<tr>
<td><em>Caryedon serratus</em></td>
<td>groundnut borer</td>
<td>groundnut, tamarind seeds</td>
</tr>
<tr>
<td><em>Corcyra cephalonica</em></td>
<td>rice moth</td>
<td>rice, maize, soybean, groundnut, cacao, dried fruits, copra, flour</td>
</tr>
<tr>
<td><strong>Cryptolestes ferrugineus</strong></td>
<td>rusty grain beetle</td>
<td>maize, wheat</td>
</tr>
<tr>
<td><strong>Cryptolestes pusillus</strong></td>
<td>flat grain beetle</td>
<td>maize</td>
</tr>
<tr>
<td><strong>Dysdercus koengii</strong></td>
<td>red cotton bug</td>
<td>cotton seeds</td>
</tr>
<tr>
<td><strong>Ephestia cautella</strong></td>
<td>tropical warehouse moth</td>
<td>rice, maize, mungbean, soybean, groundnut, flour, dried fruits, copra</td>
</tr>
<tr>
<td><strong>Lasioderma serricorne</strong></td>
<td>tobacco beetle, cigarette beetle</td>
<td>tobacco, spices, cacao, tapioca, garlic, chili, pepper, flour</td>
</tr>
<tr>
<td><strong>Latheticus oryzae</strong></td>
<td>long-headed flour beetle</td>
<td>maize</td>
</tr>
<tr>
<td><strong>Necrobia rufipes</strong></td>
<td>copra beetle, red- legged ham beetle</td>
<td>copra, dried fruits, pulses, cacao, ham, bacon, dried fish, dried meat</td>
</tr>
<tr>
<td><strong>Oryzaephilus mercator</strong></td>
<td>merchant grain beetle</td>
<td>oilseeds, groundnut, maize, dried fruits</td>
</tr>
<tr>
<td><strong>Oryzaephilus surinamensis</strong></td>
<td>saw-toothed grain beetle</td>
<td>all cereals, pulses, spices, tobacco, dried fruits, flour, sugar</td>
</tr>
<tr>
<td><strong>Plodia interpunctella</strong></td>
<td>Indian meal moth</td>
<td>rice, wheat, maize, sorghum</td>
</tr>
<tr>
<td><strong>Rhizopertha dominica</strong></td>
<td>Australian wheat borer, wheat borer beetle</td>
<td>paddy, rice, maize, sorghum, root crops</td>
</tr>
<tr>
<td><strong>Sitophilus granarius</strong></td>
<td>granary weevil</td>
<td>rice, wheat, maize, sorghum</td>
</tr>
<tr>
<td><strong>Sitophilus oryzae</strong></td>
<td>rice weevil, black weevil</td>
<td>rice, maize, wheat, sorghum, pulses</td>
</tr>
<tr>
<td><strong>Sitophilus zeamais</strong></td>
<td>maize weevil, corn weevil</td>
<td>maize, also other cereals</td>
</tr>
<tr>
<td><strong>Sitotroga cerealella</strong></td>
<td>angoumois grain moth</td>
<td>paddy, wheat, maize</td>
</tr>
<tr>
<td><strong>Stegobium paniceum</strong></td>
<td>spice beetle</td>
<td>cardamom, some other spices</td>
</tr>
<tr>
<td><strong>Tenebraeles mauritianus</strong></td>
<td>cadelle</td>
<td>all cereals, starch, bread, dried fruits</td>
</tr>
<tr>
<td><strong>Tinea granella</strong></td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td><strong>Tribolium castaneum</strong></td>
<td>red flour beetle, red weevil, flour weevil, bran bug</td>
<td>all cereals, starch, pulses, oilseeds, spices, dried fruits</td>
</tr>
<tr>
<td><strong>Tribolium confusum</strong></td>
<td>confused flour beetle</td>
<td>flour, wheat, maize</td>
</tr>
<tr>
<td><strong>Trogoderma granarium</strong></td>
<td>Khapra beetle</td>
<td>all cereals</td>
</tr>
</tbody>
</table>

**Microorganisms:** Microorganisms that cause damage to stored products include a wide variety of storage fungi, bacteria, and actinomycetes.

**Fungi:** Storage fungi are generally present as mycelia below the pericarp, or as dormant spores on the surface of seeds. They cause spoilage of stored foods through discoloration, loss of viability, heating and mustiness, biochemical changes leading to quality loss and production of toxins. Among the most serious is *Aspergillus flavus*, which produces ‘aflatoxin’ on many grains and oilseeds, and causes quality deterioration. Aflatoxin and other mycotoxins are highly poisonous and carcinogenic compounds. *Aspergillus* and *Penicillium* are important fungi that are generally associated with stored products. The nutritional status of grain, moisture, temperature, infestation by insects, mites and foreign matter, influence the microbial invasion and subsequent spoilage during storage. Some of the important fungi associated with storage loss are given in Table 2.

**Bacteria:** Bacteria pose relatively few problems in grain and dry products as they are associated with processed foods. Important food spoilage bacteria include *Bacillus, Clostridium, Staphylococcus* and *Salmonella*.

**Actinomycetes:** Actinomycetes are a group of microorganisms classified with bacteria, but whose cells are elongated and branched. *Thermoactinomycetes* spp. grows on cereals in storage where heating has taken place. Inhalation of spores during handling of such highly contaminated produce can cause lung disease in human.

**Miscellaneous Invertebrates:** These include nematodes and various kinds of arthropods. However, they cause much less damage to stored food as compared to insects and microorganisms.
Table 2. List of Important Storage Fungi*

<table>
<thead>
<tr>
<th>Species</th>
<th>Foodgrains</th>
<th>Effect on grain</th>
<th>Possible toxicity</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Aspergillus flavus</em></td>
<td>maize, wheat, soybean</td>
<td>kills and discolors germs, decays and discolors whole</td>
<td>produces aflatoxins</td>
</tr>
<tr>
<td><em>Aspergillus restrictus</em></td>
<td>maize, wheat, sorghum</td>
<td>kills and discolors germs, causes rapid heating</td>
<td>not known to use compounds</td>
</tr>
<tr>
<td><em>Aspergillus glaucus</em></td>
<td>maize, wheat, sorghum</td>
<td>kills and discolors germs, causes mustiness and caking</td>
<td>toxic to animals</td>
</tr>
<tr>
<td><em>Aspergillus candidus</em></td>
<td>maize, wheat, sorghum</td>
<td>kills and discolors germs of seeds very rapidly, causes heating, discolouration of entire kernels and total decay</td>
<td>produces toxin ‘Ochratoxin’</td>
</tr>
<tr>
<td><em>Aspergillus ochraceus</em></td>
<td>maize, wheat, sorghum</td>
<td>kills and discolors germs</td>
<td>produces compounds toxic to various kinds of animals</td>
</tr>
<tr>
<td><em>Penicillium</em></td>
<td>maize, wheat, sorghum</td>
<td>kills and discolors germs and whole kernels of seeds, causes mustiness &amp; caking, involved in early stages of heating</td>
<td></td>
</tr>
</tbody>
</table>

* Modified from Srivastava (1988)

Vertebrates

Vertebrate pests include rodents and birds, which are responsible for causing severe losses in stored grains and other stored products at farm and commercial levels.

**Rodents:** Rodents not only consume grains, but are the cause of quality losses and cause contamination. Rodents also spread several diseases to man and animals. Although a large number of species of rodents exists, only a few such as the roof rat (*Rattus rattus* Linn.), brown rat (*Rattus norvegicus* Berk.), mouse (*Mus musculus* Linn.), mole rats (*Bandicota bengalensis* and *B. indica*) are important species in most areas in the tropics. Physical, chemical and biological techniques are effectively used in controlling rats. No traditional methods have been found to be effective against rats.

**Birds:** Birds also pose specific problems around food stores and warehouses. They make nests, feed, destroy bags, and cause contamination through droppings and feathers. The birds, which generally flock to storage facilities, are pigeons, doves, sparrows, parrots and crows. Effective control techniques for birds include physical, biological and chemical methods. Strychnine derived from a medicinal plant, snake wood (*Strychnos nux vomica*), is quite effective in controlling birds, but it is highly toxic.

Storage Losses

A number of estimates have been made with respect to storage losses due to
attacks by pests. These include those caused by insects, microorganisms and miscellaneous groups.

**Insect Damage**

Insects are the major cause of loss of stored food. As early as 1967, an FAO study estimated worldwide annual losses in storage due to insect damage as high as 10% of all stored cereals, which amounted to 13 million tons of grain lost in that year alone (Wolpert 1967). In large countries like China and India, such losses may account for an enormous quantity of grains being lost unnecessarily. The figure of a 10% loss due to insect damage still remains valid even at a much later date. For example, Lal (1988) reported that in India, food grain loss during storage at the farm level was about 10%. However, in other areas, the amount of loss may be higher. For example, in Africa, an FAO study estimated the grain loss in maize and pulses, because of infestations from weevils, bruchids, and other insects to be between 20-50% (FAO 1985). Similarly, in Sub-Saharan Africa, Dichter (1976) estimated the loss during storage at farm or village to be 25-40%.

**Microbial Damage**

A number of storage fungi attacked stored foodstuffs and caused some loss to the grains. However, the most important damage is caused by *Aspergillus flavus*, which produces aflatoxin, a substance toxic to animal including man, as it has a strong positive association with the risk of developing primary liver cancer. In one of the farm surveys Quitco *et al.* (1987), reported that groundnuts in storage at farms, aflatoxin continued to increase at the rate of 1.4 ppb per day, while in the wholesalers’ warehouse for more than three months contained 275 ppb aflatoxin.

**Other Damages**

Rodents and birds caused considerable damage, but the exact figures are currently not available.

**Botanicals and Inert Materials Used in Stored Food Protection**

Several kinds of materials are used as a means of stored food protection, including chemical fumigation, treatment with synthetic pesticides, botanicals and inert materials, only the last two will be treated, reasons for which has already been mentioned earlier.

**Types of Botanicals Used in Stored Food Protection**

Botanicals are plants or plant-derived products having active ingredients for the control of storage pests. These are (i) spices, and (ii) medicinal and other plants.

**Spices:** In addition to being used to flavour foods, spices have been used from ancient times to protect stored products from pests. Traditionally, pieces of dried spices or ground spices were used to sprinkle over or mix with stored foods, but recently the use of extracts or oils has been experimentally tried with encouraging results. The list of spices used in stored food protection is given in Table 3. Among the most common spices used in storage food protection are:

- **Ginger:** It has been generally known that ginger is effective against a number of stored insect pests. For example, it caused adult mortality in *C. chinensis*, and had a repellent effect on *T. castaneum* (Ho 1995).

- **Turmeric:** Turmeric has been reported to be repellent against a number of storage insects (Jilani and Su 1983; Jilani and Saxena 1990). Chandler *et al.* (1991) reported that turmeric powder applied to rice did not cause *T. castaneum* and *S. zeamais* to suffer significant mortality during a 21-day exposure, and that after 3- and 6-month storage, turmeric treat-ments
of rice only suppressed more than 50% of the F1 progeny. Unjitwatana et al. (1997) reported that essential oils from turmeric could be used as insecticides, while tumerone was effective as a repellent against stored grain insects.

**Clove:** Clove buds have been found to repel T. castaneum and kill Ctenocephalides canis and Pediculus humanus humanus (Grainge and Ahmed 1988). Recently, Ho (1995) reported that non-polar clove extracts were very effective against adult S. zeamais and eggs of T. castaneum. Moreover, these extracts could suppress F1 progeny production in both species of beetles, implying an ovicidal action of these extracts. Besides being insecticidal, clove extracts were repellent to S. oryzae. The repellent effect of cloves against stored grain insects is well documented (Grainge and Ahmed 1988).

**Star Anise:** Non-polar star anise extracts were also found by Ho (1955) to be effective against adults and eggs of T. castaneum, but not able to kill S. zeamais, although their F1 progeny production was completely suppressed. This fact led her to suggest that S. zeamais eggs were probably very susceptible to the extracts.

**Garlic:** Garlic has been well known to have repellent effects on S. zeamais. It was also shown to repel T. castaneum (Mohiuddin 1987). Ho (1995) reported that garlic oil showed pronounced insecticidal action against adults of T. castaneum and S. zeamais.

**Greater Galangal:** It is well known in many Asian countries that the rhizome of greater galangal (Alpinia galanga) can be used as an insecticide. As for storage pests, Visetson (1994) applied its extracts for the control of T. castaneum and S. zeamais.

**Black Pepper:** Morallo-Rejesus et al. (1990) reported that black pepper could inhibit the development of F1 progenies of C. chinensis.

**Medicinal and Other Plants:** In addition to spices, many other botanicals have also been used to combat stored pests. Among these are medicinal plants, which are normally used to cure human’s illness, but can also be used to protect stored food; others are plants which are known to have effects on stored pests. The list of botanicals (other than spices) used in stored food protection is given in Table 4. Among the common botanicals are the following:

**Neem:** Neem is probably the oldest botanical, which has been used as botanical pesticides. Its use in stored food protection has also been well known, especially in South Asian countries.

**Sweet Flag:** Rhizomes of sweet flag is used as medicinal plants, for example in epilepsy and other mental ailments, chronic diarrhoea and dysentery. They are also used in stored pest protection but they are quite rare and become expensive.

**Sugar Apple:** The seeds are toxic to many insects. Its leaves have certain ingredients that inhibit the growth of certain stored grain insects.

**Indian Privet:** Its leaves exhibit insecticidal property against stored grain insects.

Table 3. List of spices used in stored food protection

<table>
<thead>
<tr>
<th>Scientific name</th>
<th>Common name</th>
<th>Effect on storage pests</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Allium sativum</td>
<td>garlic</td>
<td>Repels T. castaneum</td>
<td>Mohiuddin 1987</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Oil kills T. castaneum</td>
<td>Ho 1995</td>
</tr>
<tr>
<td></td>
<td></td>
<td>and S. zeamais</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Strong repellent for T. castaneum and S. zeamais</td>
<td>Ho 1995</td>
</tr>
</tbody>
</table>
**Alpinia galanga** greater galangal  
Extracts are insecticidal to *S. zeamais* and *T. castaneum*  
Visetson 1994

**Curcuma longa** turmeric  
Repels a number of stored insects  
2% powder mix with rice and wheat can protect attack of storage pests  
Jilani and Su 1983

**Illicium verum** star anise  
Extract kills adults and eggs of *T. castaneum*  
Ho 1995

**Piper nigrum** black pepper  
Inhibit development of *F₁* of *C. chinensis*  
Morallo-Rejesus *et al.* 1990

**Syzygium aromaticum** clove tree  
Repels *T. castaneum*  
Grainge & Ahmed 1988

**Zingiber officinale** ginger  
Cause adult mortality in *C. chinensis* and repel *T. castaneum*  
Ho 1995

they are quite different. These include neem (fruits and seeds), sugar apple (seeds), black pepper (fruits), chili peppers (fruits), etc.

### Parts of Botanicals used in Stored Food Protection

**Leaves:** Leaves are the most convenient and economical parts of plants to be used as botanical pesticides to control storage pests as they are easily harvested without too much damage to the plants, and are abundantly available during the growing season. The common kinds of plants whose leaves are used in stored food protection are neem, citronella, lemongrass, mandarin, holy basil, hairy basil, etc.

**Fruits, Seeds, and Kernels:** For convenience, these structures are grouped together, although botanically speaking, they are quite different. These include neem (fruits and seeds), sugar apple (seeds), black pepper (fruits), chili peppers (fruits), etc.

**Stem and Bark:** These are stems and barks of plants, mostly spices, which contains active ingredients to combat storage pests. These are barks of cassia, cinnamon, etc.

**Underground Organs:** Many plants possess underground organs such as roots, tubers, bulbs, and corms as storage organs. Certain active ingredients for combating storage pests are present in several species such as: greater galangal, turmeric, sweet flag, garlic, onion, *Costus*, etc.

### Table 4. Other botanicals used in stored pest protection.

<table>
<thead>
<tr>
<th>Scientific name</th>
<th>Common name</th>
<th>Traditional Uses</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Acorus calamus</em></td>
<td>sweet flag</td>
<td>Rhizome powder gave protection to wheat and paddy in storage for 8 mos.</td>
<td>Chaterjee 1980</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Oil is toxic to <em>S. oryzae</em> and <em>S. cerealella</em></td>
<td>Teotia &amp; Tewari 1977</td>
</tr>
<tr>
<td><em>Adhatoda vasica</em></td>
<td>‘Vasaka’</td>
<td>Resin toxic to stored grain insects</td>
<td>Dastur 1951</td>
</tr>
<tr>
<td>1976</td>
<td></td>
<td>Leaf powder effective against <em>S. oryzae</em></td>
<td>Chellappa &amp; Chelliah</td>
</tr>
<tr>
<td><em>Agave americana</em></td>
<td>century plant,</td>
<td>Leaves are used against</td>
<td>Grainge and Ahmed 1988</td>
</tr>
<tr>
<td></td>
<td>American aloe</td>
<td>stored grain pests</td>
<td></td>
</tr>
<tr>
<td>Species</td>
<td>Common Name</td>
<td>Description</td>
<td>References</td>
</tr>
<tr>
<td>-------------------------------------</td>
<td>------------------------------</td>
<td>-----------------------------------------------------------------------------</td>
<td>------------</td>
</tr>
<tr>
<td>Annona reticulata</td>
<td>bullock’s heart</td>
<td>Seed is insecticidal to <em>C. chinensis</em></td>
<td>Hussain and Masood 1975</td>
</tr>
<tr>
<td>Annona squamosa</td>
<td>sugarapple, custard apple</td>
<td>Leaf extract inhibits growth of <em>S. cerealella</em></td>
<td>Grainge and Ahmed 1988</td>
</tr>
<tr>
<td>Artemisia absinthium</td>
<td>absinthe, wormwood, madderwood</td>
<td>Leaf used as an insecticide against <em>S. cerealella</em>, <em>S. granarius</em> and <em>T. granella</em></td>
<td>Grainge and Ahmed 1988</td>
</tr>
<tr>
<td>Azadirachta indica</td>
<td>neem</td>
<td>Almost every part is pesticidal but seed kernel has maximum pesticidal activity. Some of insect pests of stored products which are susceptible to neem are <em>T. granarium</em></td>
<td>Numerous references Ketkar 1987</td>
</tr>
<tr>
<td>Calophyllum monophyllum</td>
<td>‘Undi’</td>
<td>Oil used as surface protectant against pulse weevils</td>
<td>Ketkar 1987</td>
</tr>
<tr>
<td>Cedrus deodara</td>
<td>Himalayan cedar</td>
<td>Wood oil as grain protectant against rice weevil for 30 days at dosage 1000 ppm</td>
<td>Singh et al. 1989</td>
</tr>
<tr>
<td>Melia azedarach</td>
<td>Chinaberry</td>
<td>Leaf and drape powders (1 and 4 %)</td>
<td>Teotia &amp; Tewari 1971</td>
</tr>
<tr>
<td>Parthenium hysterophorus - Pongamia glabra</td>
<td>pongam oil tree, Indian beech lac tree, Macassar oil tree</td>
<td>Extract is repellent against <em>T. castaneum</em> Protect wheat against <em>S. cerealella</em></td>
<td>Naga Sampagi &amp; Sharma 1982 Ahmed &amp; Koppel 1987</td>
</tr>
<tr>
<td>Schleichera trijuga</td>
<td>-</td>
<td>Oil used as surface protectant against pulses weevils</td>
<td>Ketkar 1987</td>
</tr>
<tr>
<td>Tephrosia villosa</td>
<td>-</td>
<td>Extract kills adults of <em>S. zeamais</em> and eggs of <em>T. castaneum</em>. It also repels both species</td>
<td>Ho 1995 Puttarudian &amp; Bhatta 1955</td>
</tr>
<tr>
<td>Vitex negunda</td>
<td>Indian privet</td>
<td>Leaves have insecticidal property against stored grain pests</td>
<td>Ahmed &amp; Koppel 1987</td>
</tr>
</tbody>
</table>

**State of Materials**

The state of these botanical materials applied in stored pest protection vary from being fresh materials, dried, etc. to plant extracts. These are:

- **Fresh Materials:** These are fresh parts of plant such as: leaf, twig, flower, and fruit.

- **Dried Materials:** These are dried parts of plant such as: leaf, flower, fruit, rhizome, and seed.

- **Chipped Materials:** These are materials, normally dried parts of plant, chipped into small pieces for easy handling, storage and use.

**Ground Materials:** These are materials, normally dried parts of the plant, ground into coarse particles for easy handling, storage.

**Powders:** These are dried parts of plants ground into a powdered form.

**Fixed Oils:** These are oils normally extracted from certain plant parts through simple processes such as expressing, boiling, etc. Neem oil, for example, is extracted by boiling neem leaves or kernels. It provides an extremely effective and cheap method of protection for stored beans, cowpeas, and other legumes. It keeps them free of bruchid-beetle infestations for at least 6 months, regardless of whether the beans...
were infested prior to treatment (Zehr 1984). The process may be unsuitable for use in large-scale food stores, but is potentially valuable for household use and for protecting seeds being held for planting. The treatment in no way inhibits the capacity of the seeds to germinate.

Other commercially available vegetable oils applicable in stored food protection include: coconut oil, soybean oil, groundnut oil, corn oil, ricebran oil, sunflower oil, palm oil, etc.

**Essential Oils:** These are aromatic compounds present in special glands in certain parts of aromatic plants, which can be extracted by various physical and chemical means such as: steam distillation (a process well known to farmers as they have experience with spirit distillation), expression, boiling of plant part, etc. Essential oils have played an important role in stored food protection, as they are effective, easily accessible and applicable (normally by mixing with the stored products). The essential oils effective against stored insects are those which contain terpenoids, including monoterpenes, sesquiterpenes, and other terpene derivatives. Most monoterpenes are pleasantly aromatic and exhibit low toxicity to mammals, making them good candidates for use as insecticides for pest control in stored grains and other stored food products. Shaaya et al. (1991) found five compounds extracted from 11 plants, which exhibited positive activity against three major storage pests, *R. dominica*, *O. surinamensis*, and *S. oryzae*. Limonene, one of the most studied monoterpenes, acts as a contact toxicant to a number of insects including *C. maculatus* (Palevitch and Craker 1994).

Certain essential oils possess antifungal, antibacterial, and anthelminitic properties. A list of essential oils effective against storage fungi is presented in Table 5.

**Other Extracts:** These are constituents derived from plant parts normally through a simple extraction process; the product is normally a crude extract, which can be readily used without further purification. Extracts may contain oils (both fixed and essential mentioned above), but also various other constituents effective against storage pests. Extracts of neem kernel, citronella leaves, galangal rhizomes, turmeric rhizomes, etc. are applied in stored food protection.

**Inert Materials**

There is a common tradition among subsistence farmers to use natural products such as: ashes, charcoal, sand, salts, etc. instead of chemical pesticides, and these alternatives have appeared to increase in importance. Their origins are of two sources, organic and inorganic. The material can be further classified as being ‘fine’, ‘coarse’ or ‘fragmented’, depending on their size.

**Organic:** These are materials derived from plant sources such as: ashes (e.g. wood ash, burnt rice husk) and charcoal of various sizes from fine through coarse particles, to small and large pieces.

**Inorganic:** These are materials derived from inorganic origins such as: sand, salts (sodium, potassium, magnesium, etc.), of various sizes.

A list of inert materials used in stored food protection is given in Table 6.

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**Table 5. List of essential oils effective against storage fungi***

<table>
<thead>
<tr>
<th>Essential-oil bearing plants</th>
<th>Inference</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Apium graveolens</em> (leaf), <em>Azadirachta indica</em>, <em>Curcuma aromatica</em>, <em>C. cassio</em>, <em>Myristica</em></td>
<td>All are quite active</td>
<td>Kher and Chaurasia 1978</td>
</tr>
</tbody>
</table>
**Protection Mechanisms**

Plants and plant products can affect insects and other storage pests in various ways. They may exhibit pest control activity as toxicants, attractants, repellents, antifeedants, and as growth regulators. They are also effective as antimicrobials and antifungals. A description of each is given below:

**Toxicants**

Many plants and plant products (particularly extracts and essential oils) possess insecticidal properties.

**Attractants**

Attractants are physiologically active chemical substances, which elicit oriented movements by insects towards their source. Attractants may consist of pheromones, natural food lures, oviposition lures, and poison baits. Although not considered true insecticides, as they do not kill insects, they do alter the physiological activities of insects to such an extent that insects do not perform their normal functions.

**Repellents**

Repellents are deterrents that cause the insect and other pests (especially rodents) to avoid contact with their targets in stored products.

**Antifeedants**

Various medicinal plants and spices that exhibit strong inhibitory activity in feeding certain insects. The chemical compound, absinthin, for example, isolated from *Artemisia absinthium* develops a variable feeding ratio, depending on the age and the rearing medium.


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**Table 6. List of inert materials used in stored food protection**

<table>
<thead>
<tr>
<th>Inert material</th>
<th>Stored product and method of application</th>
<th>References</th>
</tr>
</thead>
</table>

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Juvenile Hormones

This hormone prevents the metamorphosis of immature insects by maintaining the juvenile (or larval) characteristics of growing insects. It is sometimes called an insect growth regulator (IGR).

Antimicrobial Effect

Extracts of medicinal plants and spices are used to control the growth of plant diseases in storage conditions. In recent years, many investigators have indicated clearly the effectiveness of plant extracts in providing new models of natural products with strong antifungals and other biological activities.

Smith (1962) in his review article had emphasized the development of fungicides based on essential oils in the control of storage fungi. Many workers have found that a number of essential oils such as: eucalyptus, lavender, lemongrass, rosemary, bergamot, cinnamon leaf, wormwood, turpentine, etc., possess potent antibacterial and antifungal properties.

Methods of Application

Various techniques are used in the application of botanicals in stored food protection. These are:

Surface Contact

This method works by applying botanicals on the surface of the product, either by covering it with part of the plant (e.g. leaf, bark twig, etc.), or by sprinkling chipped, ground material, powder, extract, or inert materials (e.g. ash) over the stored product.

Admixtured with Stored Products

This method consists of incorporating the botanicals or inert materials into the product by mixing powder, ground material, oil, or inert material (sand and ash) with the product.

Placement underneath Stored Products

This is accomplished by placing botanicals or inert materials at the bottom of the container prior to pouring products into the container.

Traditional Methods Applied in Thailand

Plant materials have been used in the control of storage pests in many parts of the world. Examples of these methods include:

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ash (wood)</td>
<td>Mix or sprinkle in sack of rice to protect against weevil</td>
</tr>
<tr>
<td>Ash (burnt rice husk)</td>
<td>Mix with rice to protect against weevil</td>
</tr>
<tr>
<td>Charcoal</td>
<td>Place in rice container to protect against weevil</td>
</tr>
<tr>
<td>Charcoal</td>
<td>Washed and dried, place at bottom and top of rice container to protect</td>
</tr>
<tr>
<td>Salt (NaCl)</td>
<td>Mix with turmeric powder and mustard oil to age basmati rice</td>
</tr>
<tr>
<td>Salt (NaCl)</td>
<td>Mix or used as solution for rice, maize and mungbean against weevils</td>
</tr>
<tr>
<td>Magnesium carbonate</td>
<td>Protectant of wheat seed against Trogoderma granarium</td>
</tr>
</tbody>
</table>

Smith (1962) in his review article had emphasized the development of fungicides based on essential oils in the control of storage fungi. Many workers have found that a number of essential oils such as: eucalyptus, lavender, lemongrass, rosemary, bergamot, cinnamon leaf, wormwood, turpentine, etc., possess potent antibacterial and antifungal properties.
world since ancient times. In Africa as well as in Asia, for example, there is much evidence that farmers used plant parts such as leaves, bark, seeds, as well as vegetable oils to control storage pests. This practice has been passed on from generation to generation and has become a tradition in many countries, only to be abandoned with the advent of modern synthetic insecticides.

Numerous problems have recently been encountered with the use of modern insecticides, so there has been a resurgence of interest in the use of botanical pesticides, including those used for the control of storage pests. Such pesticides have been found to be non-persistent in the environment, of low mammalian toxicity, and relatively safe to other non-target organisms. This paper will now discuss research relevant to the application of botanical pesticides, particularly those derived from spices and medicinal plants, and also inert materials, which are traditionally applied to control stored food pests in Thailand.

The Stored Product Insect Pests Section (1973) of the Division of Entomology and Zoology, Department of Agriculture, compiled and published a manual on important stored product insect pests, which are comprised of 16 species commonly found in Thailand. Control measures were also described, including the use of medicinal plants and spices, vegetable oils, as well as inert materials such as starch, ashes, sand and salt. It is also recommended the use of palm oil or ricebran oil, at the rate of 5-10 ml/kg of seeds, as effective in protection from pulse weevils for at least 4 months. The next most effective vegetable oils are groundnut oil and corn oil.

Kanta et al. (1989) made a survey in Northeastern Thailand on traditional methods of using insecticides and other locally available materials to control stored pests. This is probably the only survey conducted related to traditional methodology on stored pest protection. Altogether, 90 interviews were made on stored food protection. Those using spices and medicinal plants and inert materials are summarized in the Table 7.

Visaratanonth et al. (1989) mixed mungbean seeds with a mixture of fresh ground neem fruits (2 parts); leaves (1 part) and flowers (1 part) at the ratio of 10, 20, 30 and 40 g per 250 g of stored seeds. Only the highest ratio (40 g) gave some protection against weevils. The germination of mungbean seeds after the experiment was not affected. In another parallel experiment where neem oil was mixed with mungbean seeds at the rate of 5, 10 and 15 ml per 1 kg of mungbean seeds, it was found that the lowest concentration (5-ml) gave good protection for a period of 4 months. While the higher concentrations of 10 and 15 ml gave a 5-month protection period with a somewhat reduced protection.

Nilpanich et al. (1989) mixed heat-treated maize seeds, which were infected with maize weevil, with various amounts of neem oil (5, 10, 15 and 20 ml per 1 kg of seed) and conducted evaluations at 1, 3, 5, 7 and 9 months after mixing. It was found that at concentrations of 5 and 10 ml, the protection period was 3 months; while at concentrations of 15 and 20 ml, the period was extended to 5 months without affecting the germination rate of maize seeds. The longer the period after mixing neem oil with seeds the lower was the efficacy of neem oil, but there was no significant difference in seed germination, although at 7 and 9 months after mixing, the germination rate was somewhat reduced.

Table 7. Botanicals and inert materials used in stored food protection in Thailand.

<table>
<thead>
<tr>
<th>Botanicals &amp; inert materials</th>
<th>Stored products</th>
<th>Pests</th>
<th>Application method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ashes</td>
<td>rice</td>
<td>weevil</td>
<td>mix or sprinkle in sack</td>
</tr>
<tr>
<td>Charcoal</td>
<td>rice</td>
<td>weevil</td>
<td>place in container</td>
</tr>
</tbody>
</table>

43
Charcoal (washed, sun-dried)           rice              weevil   place at bottom & top of container
Salt              rice   weevil   mix, solution
Salt              maize   weevil   mix
Salt              mungbean  weevil   mix
Burnt rice husk            rice   weevil   mix
Chili (dry)             rice                     weevil   place in container with closed lid
Chili (grilled)             rice    weevil   place in container
Tobacco leaves (dry)                         rice   weevil   place in bin
Tobacco leaves (dry)                       paddy   weevil   place in container with lid
Makrut leaves (dry)            stored products  weevil   place in container
Makrut leaves (dry)                       rice   weevil   place in bin
Mandarin leaves (dry)                       rice   weevil   mix
Lemongrass stems and leaves           rice   weevil   place in bin
Holy basil             rice   weevil   mix

Source: Kanta et al. 1989.

Visaratanonth et al. (1992a) mixed citronella oil with mungbean seeds at the rates of 0.5 and 1.0 % and found it to be effective in controlling C. chinensis under storage conditions. They also found that citronella oil did not have any effect on the germination rate of mungbean seeds. In another experiment, Visaratanonth et al. (1992b) used commercially available neem extracts, Javan and Neem Bond A, to control C. chinensis by mixing mungbean seeds with 0.2, 1.0, 1.5 and 2.0 % of the extracts and keeping them in glass jars infected with 50 1-3 day-old weevils. The efficacy of the extracts in controlling the weevils was checked at the end of each month for five months. It was found that Neem Bond A at 2.0 % gave the best protection since no damage was evident at the end of the experiment (5 months), while concentrations of 1.0 and 1.5 % of the same extract could be effective for only 1 and 2 months, respectively.

Nilpanich et al. (1992) mixed maize seeds with neem extracts containing 0.002 % azadirachtin at the rates of 5, 10 and 20 ml per 1 kg of seeds, placed them in a cloth bag and kept them in storage. It was found that all three concentrations of neem extracts were effective in controlling maize weevil for a period of 4 months.

Five species of Thai medicinal plants, namely holy basil (Ocimum sanctum), sugarapple (Annona squamosa), aloe (Aloe vera), Thai neem (Azadirachta siamensis) and bitter bush (Eupatorium odoratum) were tested by Soonwera (1992) for the control of C. chinensis. Leaves of these plants were ground and mixed with mungbean seeds (at the rate of 2 g per 20 g of mungbean seeds) following which five pairs of adult insects were allowed to lay eggs on them for one day. It was found that neem gave the best result in controlling the damage caused by the pulse weevils for a period of 30 days, while bitter bush, aloe, holy basil and sugar apple could prevent damage for a period of 25, 25, 24.8 and 22 days, respectively.

Soonwera (1997) tested thirteen species of medicinal plants and seven vegetable oils for controlling C. maculatus. These medicinal plants included: orange jessamine (Murraya paniculata), Justicia fragilis var. variegata, celery (Apium graveolens), hibiscus (Hibiscus rosa-chinensis), sugarapple (Annona squamosa), betel leaf vine (Piper betel), Madagascar periwinkle, tobacco, crown flower (Calotropis gigantea), castor bean (Racinuss communis), bastard cedar (Melia azedarach), and catechu tree (Acacia catechu). They were ground into fine particles and then, using 0.5 to 1 g, mixed with 10 g of mungbean seeds and 0.01 ml of vegetable oils. Ten pairs of adult
weevils (2 days old) were placed into the container of mungbean seeds. The experiment was conducted in the laboratory at 29.7°C and 81.8% RH using 0.51 g ground medicinal plants and 0.01 ml of vegetable oil per 10 g of mungbean seeds. The results showed that three treatments, i.e. castor bean + sugarapple, castor bean + bastard cedar, and tobacco were able to effectively inhibit hatching of the weevils’ eggs. The efficacy in order of decreasing of effectiveness: bastard cedar + sugarapple, ricebran oil, castor oil, sesame oil, soybean oil, bastard cedar, corn oil, safflower oil, and olive oil.

Unjitwatana and her co-workers (1997) extracted and isolated various compounds from turmeric (Curcuma longa) and bitter bush (Eupatorium odoratum) and used them in their bioassay study with two storage pests, C. maculatus and S. oryzae. They found that essential oils of both plants could be used to control storage pests. Essential oils and alkaloid from bitter bush could be used as insecticides.

Neem oil was found to reduce the density of S. zeamais in maize seed stored for 90 days (Attanon 1997). Neem oil added to mungbean seeds was found to keep damage by C. maculatus at low levels for at least 90 days (Seema et al. 1995).

With regards to storage fungi, Pitt et al. (1993, 1994) reported the presence of fungi and mycotoxins in nut, oilseeds, mungbeans, soybeans and rice obtained throughout the country and the distribution chain, from farmer storage, to middlemen and the retail system. They determined that the most commonly found fungus was Fusarium semitectum, which was most abundant in mungbeans, paddy rice, and blackgrams, and also common in soybeans and sorghum. Storage fungi, especially Eurotium species and the xerophilic Aspergillus, were present in only low numbers except in soybeans. Aspergillus flavus was found in nuts, oilseeds, sorghum and cassava. No control measures were mentioned in either paper, however.

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