# THE STORAGE OF FOODSTUFFS IN THE COLONIAL EMPIRE*

## INTRODUCTORY

IN Chapter IX. of the First Report of the Committee of the Economic Advisory Council on Nutrition in the Colonial Empire, consideration was given to the question of the storage and preservation of foodstuffs. In paragraphs 195 and 196 of that Report mention was made that under colonial conditions the main problems of storage are not associated with the preservation of high grade commodities for the overseas markets, but rather with the maintenance, for local consumption, of stocks from one harvest to the next, from the crops grown by the individual or community, and the preservation of perishable products in order that they may be kept for a time, and if necessary distributed over a wider area.

The suggestion was made that steps should be taken to collect information, with a view to its subsequent circulation, regarding existing storage practices in the Colonial Empire. Much knowledge based upon experience is possessed by colonial peoples in regard to the storage of small quantities of food supplies, but nevertheless there are considerable losses in many areas as the result of faulty storing, and if practice in this respect could be improved, the general food supply position would be more favourable than it is at present. Particularly is this the case where seasonal shortfalls of food are likely to occur as the result of unfavourable weather conditions and consequent crop failures, and the question of satisfactory storage assumes added importance under war conditions when imports of food from outside sources are liable to serious reduction. [1]

In the following pages an attempt has been made to summarize available information on the subject in the hope that this may assist in focussing attention on a problem which has a considerable degree of importance under the present circumstances.

## GENERAL PRINCIPLES OF STORAGE

The successful storage of foodstuffs necessitates the satisfaction of two requirements (*a*) that the product to be stored, at the time of its introduction into the store, is in a condition suitable

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* A memorandum prepared by the Agricultural Advisers to the Secretary of State for the Colonies.

for storage, and (*b*) that the conditions of storage are such as to ensure that this state of affairs may be maintained satisfactorily during the period of the storage.

If stored products become invaded by insects or other destructive agencies, treatments may be available to reduce the damage, but it is far preferable to prevent loss by attention to the provision of suitable stores and to the conditions of storage.

When considering storage, foodstuffs may conveniently be classified as follows :—

(1) the grain crops, with which may be included the pulses, and

(2) the root crops, including sweet potatoes, yams, cassava, &c.

In addition there are products prepared from grain, such as rice, flour, brans and meals, as well as dried chips and meals prepared from root crops.

Stored grains and meals are liable to insect attack and may also be damaged by the growth of moulds and fungi if the conditions of storage are unsatisfactory, whilst they may also be attacked by rats and mice if they are not adequately protected against them.

Stored grain containing more than 15 per cent. of moisture is liable to " heat " as the result of the commencement of germination and the onset of attack by moulds and bacteria. Such grain is also particularly liable to attack by weevils since the optimum conditions for the existence of these insects in grain occur when the moisture content lies between 17 and 20 per cent. On the other hand, weevils are unable to live in grain containing less than 8 per cent. of moisture, and cannot carry on active life in the absence of an adequate supply of air.

Consequently it is important to ensure that before storage the moisture content of grain be reduced to a value which will remove the liability to " heating ", inhibit the growth of moulds and afford some protection against insect attack, while during storage, conditions should provide that the moisture content of the stored grain does not increase by reason of inadequate protection. If these requirements are not satisfied loss is bound to occur ; thus experiments carried out in the Federated Malay States in 1928/30 showed that when rice is stored in bags under the conditions which normally prevail in the commercial godowns it is barely edible after eight months. On the other hand when it is stored in bags under clean, rat-proofed and well-ventilated conditions it can be kept satisfactorily and without appreciable deterioration for a period of two years. [3]

As regards the moisture content of stored grains and meals, the factor of safety varies to some extent with different types of product, but it may be said broadly that for satisfactory storage the moisture content should not exceed 12 to 14 per cent. and may with advantage be lower. Maize exported from Kenya is not permitted to have a moisture content in excess of 12·5 per cent. and if maize on receipt at Mombasa has a higher percentage it has to be reconditioned in the Maize Conditioning plant. This drying plant was obtained through the Crown Agents from Messrs. T. Robinson of Rochdale, England.

The reduction of the moisture content of grain to safe levels depends to a considerable extent on climatic conditions. Where the humidity of the air is low, grain crops can be dried in the field to satisfactory moisture content. Such conditions exist in many parts of Africa. On the other hand, where the atmospheric humidity is high, drying in the field is not practicable and special measures are required to reduce the moisture content to satisfactory levels ; these may take the form of drying on floors or barbecues, or even on the ground by the direct heat of the sun, the grain being spread out for the purpose and turned at intervals, provision being made to protect the grain from sudden showers of rain.

Various forms of grain-drier also exist in which a current of heated air is forced by blowers or suction fans through the grain ; the employment of such devices may add materially to the cost if the moisture to be driven off is considerable. Their use is mainly limited to places where large quantities of grain are handled and stored in bulk and it is doubtful whether they are capable of being economically used for the handling of relatively small quantities of grain. Driers of this type were erected and operated during the last war in two West Indian Colonies and in Mauritius, and the experience there gained indicated that under those conditions the artificial drying of grain was a doubtfully economic procedure when the initial moisture is high. The maize conditioning plant operated in Kenya at Mombasa functions satisfactorily at relatively low cost as the reduction of the moisture content of the grain before it is ready for export is generally small.

Not only must the moisture content of stored grain be reduced to a satisfactory level but it must be kept at that level during storage, and in countries where there is marked variation of climate between the wet and dry seasons this may prove a factor of importance. Many grains are hygroscopic and their keeping power is liable to be influenced by the atmospheric humidity at the place of storage. Difficulties in this direction are illustrated by the fact that the length of time for which rice can be stored without deterioration in Burma depends to an appreciable degree on the climatic conditions at the time it is milled, rice milled during the dry season possessing better keeping qualities than rice milled during the wet season.

Containers for the storage of grain should be dry ; they should be protected from invasion of moisture from the ground and also from the entrance of moist air during wet periods, while they should also be insect-proof and rat-proof.

### GRAIN : BULK STORAGE

Various methods are used by the peasantry in tropical and sub-tropical countries for the storage of grain, some of which are reasonably efficient.

Provision is made, for example, by the populations in many parts of the Colonial Empire for the careful storage of their grain crops, and each homestead has its stores made of reeds or other material carefully mudded—sometimes only on the inside but more generally on both the inside and outside walls. [10] These stores vary in size and shape, some of them being bottle shaped and spherical as in Meru, or beehive shaped as in Machakos in Kenya. In certain cases the stores are raised on posts from the ground as is common in the villages of Ceylon. In the majority of cases in Africa, the men and women own their crops individually, customs varying with different tribes, and in many areas so individual is the ownership of crops that adult members of a family keep their crops separately in different stores. In such cases the women are expected to feed the husband and the family from the store of food in their possession, whilst the husband, though he may in cases of need supplement her stocks, uses his supplies for the preparation of beer and for the entertainment of guests. In the northern territories of the Gold Coast, there is also a store of food in the keeping of the woman which is reserved for the scarcity period and this is the last of the stores in any season to be opened. Yam producers in West Africa equally store their crops individually on wooden racks, which are shaded, but exposed to the air, with the woman providing for the needs of the family and the man using his crops either for sale or for the entertainment of guests.

The grain stores are usually cleaned, and in many cases remudded or given a coating of cow dung, before the crop of the season is placed in them, and a considerable degree of knowledge is possessed by the people regarding the keeping qualities of the different types of grain raised. It is generally accepted, for instance, in West Africa that certain yellow-grained guinea corns keep for only short periods of time, whilst harder white-grained types can be stored without damage for lengthy periods. It is held with justification in many parts of Africa that the grain of bulrush millet (*Pennisetum typhoides*) is less liable to damage than is the grain of guinea corn, and again that the grain of *Eleusine corocana* keeps well if dry when stored, and is not so seriously damaged by insects as other grains.

In the drier areas of Uganda, a striking feature of the country-side is the communal storage of grain, in which are stored considerable stocks of grain from one season to another against scarcity or famine. These communal granaries, consisting of a large number of round mudded store houses with grass covered roofs, are well controlled and maintained, although so far it has not been possible to introduce a satisfactory system of protection against rat damage and the accompanying danger of providing foci for the spread of plague, which is a rat-borne disease.

In Sierra Leone also it is held that rice in which ripe pods of chilli are introduced is less liable to insect damage than where this addition is not made, but whether this claim is justified has yet to be investigated.

Very fairly efficient types of granary for the bulk storage of paddy are in use among Malay rice growers in the Malay States. [5] In the State of Kedah two types of granary occur. In their original forms, they are made of plaited bamboo, but more recently galvanized iron has also been employed. They comprise a larger square type, some of which are capable of holding several thousand bushels of paddy, and a smaller round type which holds a few hundred bushels. They are erected under cover and are raised off the ground on wooden supports which are protected by rat guards. In them paddy can be stored without depreciation for many months; if the grain is attacked the damage is usually confined to the superficial layers. In some cases the wooden supports on which the stores have been erected are not sufficiently high and the rat guards are occasionally inadequate. Rats are known to be able to make a vertical leap of 2 feet 6 inches and to crawl around flanges which are less than 9 inches in total width. Stores to be protected adequately against rats should have their floors not less than 2 feet 9 inches from the ground and be protected at this height by flanges or pieces of kerosene or petrol tins which extend from the sides of the store or its supports for a distance of not less than 4½ inches.

In Nyasaland an attempt was made in 1931/32 with some success to develop the use of communal grain stores of a type originally suggested by the Tanganyika Department of Agri-culture. They consisted of a cylindrical mudded container standing on a mudded platform about four feet from the ground. In the final form the top was also mudded and a small manhole cut in the side for filling. It was found that in stores of this type, provided they were fumigated at the commencement of storage, grain could be kept for several months without deterioration. [9]

In many parts of Africa and elsewhere maize, after drying in the field, is stored on the cob in the unhusked condition either in cribs or on beams, shelves or racks in houses. Cobs with tightly fitting sheaths are rarely infested. This method is satisfactory for keeping small quantities of maize for relatively short periods, but is not generally suitable for storing large quantities for any considerable length of time. [2]

Various types of smaller containers have also been evolved by peasant cultivators for the storage of grain. These may take the form of earthen jars or metal containers, and petrol tins have been successfully used. In the Gold Coast maize stored in airtight petrol tins showed no loss of weight and was free from weevils after eight months, while maize stored in the husk showed a loss of 25 per cent. in weight and was of less attractive appearance. [2]

In India, grain stored in metal or earthenware containers has been successfully sealed and kept airtight by covering it with a layer of sand, a sheet of cloth or a piece of iron or wood being placed beneath the sand layer to prevent the grain becoming mixed with the sand. [2]

Grain is often stored underground in India and elsewhere in more or less airtight pits. Experiments in Australia have shown this to be an effective method of controlling a number of insects which infest it, the pests being killed by the carbon dioxide given off by themselves and by the grain. This method of storage may be of value where large stocks of grain have to be stored for long periods. In using it the grain should fill the available space so that the store contains as little air as possible. [2]

For the large scale bulk storage of grain the most satisfactory method is in large metal or concrete tanks, which can be hermetically sealed and which are provided with facilities for fumigation. Where, as in parts of South Africa, maize can be dried in the field down to moisture contents of 8 to 10 per cent. it can be stored in tanks with open tops without deterioration, as at these moisture values it is largely immune from insect attack. Where storage at higher moisture content has to be undertaken closed containers are necessary.

Galvanized iron containers are probably the most efficient and economical for the storage of maize. They can be constructed in sections, the sides being riveted and soldered at the joints ;

the lower end of each section should overlap the section below to keep out air and moisture. The tank itself should rest on a wooden or concrete platform ; it is filled by means of a hole in the roof which can be hermetically closed by means of a flanged lid. Tanks of this sort are widely used in the United States of America for the farm storage of grain.

### GRAIN AND MEALS : STORAGE IN BAGS IN STORES

While the bulk storage of grain is the most satisfactory method, storage in bags often has to be undertaken, and in any case bulk storage is not in general applicable to meals, flours or rice. Under these conditions special attention should be paid to the construction of the store and to the conditions of storage. Stores are best constructed of brick or concrete, and they should at least have a concrete floor ; all corners should be rounded to prevent accumulation of debris in which insects may breed, while the sides, floor and roofs should be free from cracks and openings in which insects might harbour. They should be well ventilated and should if possible have a through draught. All windows should be screened with fine mesh wire gauze, while double self-closing doors should be provided in large stores. Satisfactory rat-proof granaries have been erected at Colombo in Ceylon and at Port Louis, Mauritius, for the storage of rice in bags. [4]

All stores should be rat proofed, since otherwise a large amount of damage may occur, while there is also the danger of providing foci for the dissemination of rat-borne diseases, particularly plague. When grain or meals are stored in bags it is important to prevent them coming into contact with the floor. This can be achieved by stacking in rows on rafters or beams running parallel with the length of the building and allowing space for circulation of air and for inspection. In Southern Rhodesia newly bagged grain is often pidgeon-hole stacked in order to hasten drying.

Maize meal does not keep well after it is ground if the germ is not removed, owing to the oil contained in the germ which rapidly turns rancid and imparts an objectionable taste to the product. Maize meal intended for storage for any lengthy period accordingly requires to be degerminated. Machines for doing so are on the market. From a nutritional point of view, however, it is undesirable to eliminate the germ, which is rich in proteins and fats and has high nutritive value. One way of meeting the difficulty is to store maize in the form of grain and to grind small quantities as required to meet immediate demands.

### PESTS AND PEST CONTROL

*Insects attacking stored grains, flour and meals.*—Grains and their products, meals and similar materials prepared from root crops are liable to attack by a number of insects. These include the grain weevils characterized by their long snouts, examples of which are the Grain Weevil proper (*Calandra granaria*) and the Rice Weevil (*Calandra oryzae*). The females may live for 4–5 months and lay from 100 to 200 eggs, from each of which a small grub hatches out and at once starts to feed. The grub or larval stage is passed inside the grain and by the time the grub is fully grown the whole of the grain has been hollowed out, and in this shell pupation takes place. The time of development depends on the temperature; the lower the temperature the longer the life of the weevil, while the life period is also affected by moisture conditions and by the kind of food.

(*b*) The Saw Toothed Grain Beetle (*Silvanus surinamensis*) which derives its common name from the presence of tooth-like projections on the lateral margins of the thorax. Both larvae and adults feed on flour meals, nuts and seeds of several kinds.

(*c*) The Flour Beetles (*Tribolium spp.*) which are commonly associated with weevils in grain damaged by the latter although they occur more commonly in flour and meals. They differ from the weevils in having no snout, and are lighter in colour and flatter bodied than the weevils, while the grub does not remain inside the grain but wanders freely through and over its food. The time of development from the egg to the adult is about forty days.

(*d*) Pea and bean weevils belonging to the genus *Bruchus*—short in body with thick snouts and prominent antennae. The larvae are short, thick grubs, which live and complete their development within the seeds of peas and beans. The female deposits eggs on or in the seed pod and the young larvae penetrate into the developing seed.

A number of moths also attack grain and flour, among which under tropical conditions various species of *Ephestia* (known as the Mediterranean Flour Moth), the Cacao Moth and the Fig Moth may be cited. These are less important than the weevils but where heavy infestation has been allowed to develop considerable damage may be done.

In addition there are a mumber of mites which attack stored grains and foodstuffs and which, although less obvious than the beetles and the moths, occur in enormous numbers and do much damage at times.

*The manner in which stored products become infested with insect pests.*—Infestation of stored products by insects may occur either (*a*) before storage, *i.e.*, in the field or in course of transit from the field to the store, or (*b*) during storage, as the result of placing them in stores which have themselves previously become infested. Infestation in the field occurs in the case of the Bean and Pea weevils, and it has also been shown that infestation of cacao beans by Pyralid moths originally commences on the plantation ; the moths come in the night and deposit their eggs on the beans exposed on the drying platforms. [6] This type of infestation cannot be entirely prevented but by proper precautions it may be reduced to a minimum. In Southern Rhodesia it has been established that maize in the fields is infested with weevils from various sources such as farm stores, maize stocked at rail-heads, shelling dumps, &c. The stores become infested by weevilly maize brought in from the fields after harvesting time.

With the liability of produce to infestation in the field it is easy to see how warehouses and granaries may become infested and lead to the infestation of produce stored therein if precautionary measures are neglected. The importance of cleanliness in barns and adjacent buildings from which insects might reach the stores accordingly cannot be too strongly emphasized.

*Precautions against infestation.*—The screening of windows and doors can do much to prevent pests from spreading, while good lighting, thorough ventilation and relatively low temperatures are also important as grain moths and weevils thrive best in dark places and a still, warm atmosphere. Store rooms should be completely emptied and thoroughly cleaned at least once a year and all emptied barrels, sacks and other containers should be sterilized before they are used again. This sterilization may be done by means of dry heat or sun or by use of boiling water. Storerooms can be disinfected by spraying or washing the floor, ceiling and walls with kerosene emulsion, diluted carbolineum or similar disinfectant preparations. Whitewashing the walls and ceilings should also be regularly effected as it assists the detection of uncleanliness and the presence of destructive insects. All rubbish and refuse from the stored product should be regularly swept up and destroyed by fire, particualrly from under the duck boards on which bags are stacked : the regular movement of stored material acts as a check on the multiplication of moths and weevils. Fresh material should never be stored with infested material or in storehouses or containers that are not scrupulously clean ; if stores become infected to such an extent that it is in practice impossible to free them from infestation they are better destroyed.

When grain has to be stored in large quantities for a considerable period it is wise to screen it when it is received, since this has the effect of eliminating weevils before they can lay their eggs, and the danger of future infestation is minimized. The longer screening is delayed the greater will be the subsequent infestation.

The problem presented by the infestation of commodities in store is twofold, namely infestation brought in by goods introduced into the store which may be called the "incoming population", and infestation of the store itself which may be called the "resident population." Generally, the destruction of the incoming population can be more easily attained than that of the resident population. Incoming goods can be treated if necessary in special containers, but the stores with their more complex structure and almost infinite capacity for harbouring insects are more difficult to clean up. It often happens that for the treatment of incoming goods fumigation is wholly satisfactory, but for cleaning storage sheds or warehouses fumigation may be impracticable or may have to be supplemented by the use of sprays. In this connection the following elementary precautions to prevent the spread of infestation deserve consideration :—

(1) Infested goods should be segregated. Containers, whether sacks or baskets or drums, which have carried infested goods should not be used again until disinfected or sterilized.

(2) Broken goods, screenings and sweepings are especially prone to infestation. They should be isolated and sterilized or burned at the earliest opportunity. On no account should sweepings be returned to the main store.

(3) New season's goods should never be stored with old season's goods unless these older goods are known to be clean.

(4) In inspecting goods for the presence of insects the following places should receive special attention :—

(*a*) between adjacent sacks and baskets ;
(*b*) between these and the walls of the store ;
(*c*) in the ears and folds at the top of sacks and in the wicker work at the tops and bottoms of baskets ;
(*d*) at the highest or the darkest places in bulked goods ;
(*e*) on the floor and especially on the walls of stores near infested goods ;
(*f*) on the floors of carts, wagons or sledges used in harvesting.

Insects and mites increase in numbers only when they have an undisturbed food supply and breeding ground. Obviously, therefore, neglected heaps of old grain or meals, sweepings, old sacks, and long accumulated debris in corners and in cracks between floorboards form ideal breeding grounds for them and the first step in the war against these pests is to see that no such breeding grounds are allowed to remain.

*The Control of Insect Pests.*—The main measures available for the protection of foodstuffs in store are fumigation, the use of insecticidal dusts, and perhaps the use of sticky substances to prevent the insects wandering.

*Fumigation.*—In spite of extensive fumigation carried out in certain countries, the general principles underlying the use of fumigation are still insufficiently appreciated, and the Department of Scientific and Industrial Research has recently thought it necessary to have prepared a pamphlet dealing with the principles of fumigation, from which some of the information given below has been taken prior to publication by permission of the Department. [11]

The first need in fumigation is the complete vaporization of the fumigant, but in warm countries this difficuty is not likely to arise. The most important cause of failure is the large amount of gas which is liable to be rendered inactive because of its absorption. This may take place on the walls of the fumigation chamber itself, on the surface of the bags, cases or boxes containing the produce, and on the surface of the produce. In consequence, ample allowance should be made for absorption of fumigant, while any fumigant so absorbed must be regarded as having little or no insecticidal effect. Further, on account of absorption of the gas by the product, the concentration of the fumigant varies inversely with the depth below the surface. Downward diffusion, therefore, does not depend entirely on whether the vapours of the fumigant are heavier than air, and it is essential to apply a dosage strong enough to provide a toxic concentration after the product has taken up all it can. Various products differ in their ability to absorb fumigants. Those rich in fat, such as nuts, absorb a high percentage of gas, and grain very little. Dry food will take up only traces of most gases. Accordingly, longer aeration is necessary after fumigation in the case of foods rich in fat. The concentration and the time during which a fumigant acts influence the depth of penetration of a gas. Therefore, a small dosage of a fumigant for a long time is as effective as a large dosage for a short time.

A further cause of ineffective fumigation lies in the unsuitable piling or stacking of the goods to be treated, and it is necessary that in such cases goods shall be stacked so as to attain the maximum exposure to the fumigant. It has been found, for example, in experiments with cacao in bags laid horizontally that one end of every bag should be exposed. Penetration is affected also by the size and disposition of the

" intergranular spaces", *i.e.*, the small spaces between the grains or beans. The proportion of these spaces varies greatly in different products, but is often surprisingly high. Effective circulation and distribution of a fumigant can often be attained by quite simple means ; for example, by the use of large fans or punkahs slung from the roof of the chamber or building and operated from outside by means of a rope or cord.

In general, the important points to observe are that adequate dosage must be given to allow for loss by absorption and leakage, and adequate provision made for effective circulation of the fumigant throughout the goods.

One difficulty in effective fumigation is that it usually results in the absorption and retention of quantities of the fumigant in the goods treated. But this is only a drawback in that it prolongs the period of ventilation of the goods necessary before they are handled or consumed. Even with hydrogen cyanide, which is one of the most penetrating of all the fumigants, " residual " gas can in most products be eliminated by the simple process of ventilation or airing the goods.

Certain goods are quite unsuitable for treatment by fumigation, especially those rich in essential oils, *e.g.*, cloves. But except in special instances, effective ventilation is a fairly reliable safeguard against residual fumigant.

*Construction of buildings and containers used for fumigation.*— The first requirement for efficient fumigation is a building or container that can be made as airtight as possible, so that the fumigant shall remain in all parts of the space at full strength and for the required time. Loss of fumigant may arise from leakage and from absorption in the materials of construction. In brick and concrete buildings in good repair the absorption loss is the more important, and the total loss may be such as to tender these buildings unsatisfactory for the routine fumigation of goods. Absorption can, however, be greatly reduced by painting exposed surfaces of absorbent material with oil paint, or with cellulose paint, but not with whitewash or distemper. Wood, brick, concrete, mortar, plaster and composition boards are all strongly absorptive, the capacity varying with the quality of the material, density of concrete, hardness of wood, &c.

Accordingly, wherever possible, goods should be fumigated in specially constructed fumigation chambers, and the cost of handling involved in this procedure is more than offset by its reliability and by a saving in fumigant which is otherwise lost through leakage and absorption. Special chambers have fixed characteristics, so that the standard result is readily obtainable. They can be made of a convenient size and should preferably be fitted with a vaporizer and with means for distributing the gas, and should be adapted to secure rapid ventilation at the end of fumigation. The use of tanks provided with a water seal is especially useful in fumigating with carbon bisulphide. The best practicable material for fumigation chambers is mild steel which is suitable for most fumigants. It is practically non-absorptive and lends itself to airtight constructions. A cheaper material which is often satisfactory is bituminous felt, supported on a wooden frame secured to a concrete floor. The joints must be made with a bituminous compound and the felt must be protected from mechanical damage and from contact with liquid fumigant, if this has any solvent action. Brick chambers painted with three coats of good oil paint are also satisfactory. When no proper fumigation chamber is available a water-tight barrel covered with double thickness wrapping paper, or an ordinary bin with a properly fitting lid, sealed with paper and paste, may be effectively used for fumigation on a small scale. When no fumigation chamber is available bags of grain or loose grain may be piled together, covered with a good tarpaulin and then fumigated. These methods give fairly satisfactory results provided the barrel or tarpaulin is gas-tight.

*Fumigants used and conditions of fumigation.*—In the Colonial Empire the choice of fumigant is restricted, and may be still more restricted in war-time. It is probable that in actual practice only two fumigants need be seriously considered, carbon bisulphide and hydrogen cyanide.

Carbon bisulphide is by far the most commonly used, although its vapours are highly inflammable and explosive when mixed with air in certain proportions ; it is also noteworthy that it is not very effective against the eggs of insects and for this reason fumigation, if efficient, should be undertaken twice, the second application being to destroy insects which may have been in the egg stage during the first fumigation. The main advantage of carbon bisulphide is that it can be used in almost any type of chamber or container. Ethylene dichloride is often employed as a substitute for carbon bisulphide when the fire hazard cannot properly be controlled. Its vapour is slightly inflammable, and both it and carbon bisulphide are frequently mixed with 25 per cent. of carbon tetrachloride to reduce the risk of fire. These mixtures are, however, unstable and not satisfactory. Carbon bisulphide is applied by sprinkling evenly over the surface of the grain to be treated by means of a watering can at the rate of from 1 to 3 gallons per 800 bushels of grain, depending upon the temperature of the grain and the tightness of the bin. If the depth of the grain in the bins is more than 5 feet it is advisable to introduce the fluid to below this depth by means of a pipe having openings at frequent intervals along its length.

The use of a tarpaulin to cover the grain after the fumigant is applied will help in confining the vapour. Higher concentrations are required if the gas cannot reach the pests so easily.

It seems, however, that under war conditions some difficulty may be experienced in obtaining carbon bisulphide in Colonial dependencies, since the material was usually conveyed only on foreign ships, because charges and conditions of transport on British ships were onerous. It seems certain that they will be still more onerous under war conditions.

An alternative fumigant is hydrogen cyanide. It is one of the oldest, and when properly handled, one of the most efficient. It is, however, very dangerous to man even in small quantities if inhaled and the strictest supervision of its use is necessary. The original method of using hydrogen cyanide was to generate it by the "pot" method from potassium cyanide and dilute sulphuric acid. This method is still employed, but is not really satisfactory for large-scale work. In temperate countries liquid hydrogen cyanide is now widely used, but it would require special packing under tropical conditions, and its transport is difficult. The most promising form of hydrogen cyanide for tropical use consists of hydrogen cyanide absorbed on some mineral earth or on papier mache discs. Two widely used proprietary brands of hydrogen cyanide are the fumigant known as "Zyklon", originally a German product which consists of hydrogen cyanide absorbed in an inert earth, and "Cyanogas", an American product consisting of a commercial form of calcium cyanide. It is probable that one or other of these brands and papier mache discs may be found most suitable under Colonial conditions. The gas is generated from these by simple exposure to air.

Calcium cyanide may also be employed, and whilst it may have the disadvantage that the gas comes off slowly, this in turn has the advantage that the slow building up of a concentration of gas is less likely to lead to high absorption of the gas by the goods than a rapid building up of a high concentration. The substances above mentioned are easily portable, reasonably easily handled, readily measured out to give the various dosages required, and can be spread out as required to ensure good distribution of gas.

The best method of determining the conditions for fumigation is as follows :—

(1) Make a thorough survey to identify the insects completely and to find out exactly the conditions under which it will be required to kill them.

(2) Find out, by experiment if necessary, the concentration of the selected fumigant and the period of exposure required to kill them.

(3) Find out, by experiment if necessary, the amount of fumigant which must be used and the best method of application so that the requisite concentration shall be maintained at every point, in the warehouse or in the goods, where there may be an insect to be killed

*Sprays.*—Many storage buildings, particularly those in tropical countries, are so constructed as to render fumigation difficult. Insect infestation in such buildings is probably best tackled by means of sprays. Insecticidal sprays may be divided into two types; those which rely on a direct hit, whereby the insect is thoroughly wetted, and those which, after atomization, ultimately settle on the insects. It is only in rare circumstances that a direct hit can be obtained on stored products insects and accordingly an atomized spray is essential. A good one consists of an extract of pyrethrum carried in a white oil (Kerosene).

Spraying equipment for this type of spray is available. It requires the use of an air compressor which may be driven by a petrol engine and particulars of the equipment are obtainable from Sterilectric Co., Ltd., and Messrs. Charles Austen & Co., both in London.

*Dusts.*—It is well known amongst colonial producers that seeds required for planting can be kept effectively free from insect attack if they are stored in vessels or tins with dry wood ashes. Experiments made by Squire in British Guiana have also shown that weevil damage in rice can be materially reduced by the addition of less than 1 per cent. of calcium carbonate (precipitated chalk) and that in the Federated Malay States it has been found at the Government Rice Mills in Perak that the treatment of stored rice with 5 per cent. slaked lime affords satisfactory protection from insect attack. In British Honduras it is a common practice to add lime when maize is stored in the cob in heaps or bins, with beneficial results.

In recent years the use of dusts for the protection particularly of grain and cereal products has become more and more general. It is unfortunate that at present no clear understanding of the action of these dusts has yet been attained and there is considerable controversy regarding it. From the practical man's point of view, however, the main point is that these dusts are said to be surprisingly effective and, further, the variety of mineral dusts which are effective is considerable. Of the natural mineral dusts, the best known and probably the most effective is a naturally occurring rock phosphate widely known in Egypt under the name of "Katelsousse". This particular dust has been so generally successful that it is now marketed on behalf of the Egyptian Government by Imperial Chemical Industries, Ltd., under that name.

Other effective dusts consist of pure silica and one of these, known under the proprietary name of "Naaki", has been widely used in Germany and elsewhere. It is a German product and will in consequence not be available during the war. Other simple mineral dusts are precipitated chalk, slate dust and china clay. It is quite probable that a number of naturally occurring earths may prove effective. Some firms market or are about to market dusts for which they claim very high efficiency, and particulars of these can be obtained from Imperial Chemical Industries, Ltd., and Messrs. Peter Spence & Co.

The use of dusts is simple and consists merely in the mixing of the dusts with the grain or other product to be protected. Their general use is for the protection of grain and seeds, particularly pulses. It is worth noting that while experiments on the elimination of these dusts prior to milling and baking of grain are still in progress, the general opinion is that this elimination need present no difficulty, and further that many of the dusts mentioned are innocuous to the alimentary tract. Where dusts such as lime or powdered chalk are used in stored rice their elimination occurs when the rice is washed, as is customary, prior to cooking.

Of all the methods of protecting grain and seeds in particular against insect attack it would seem that the use of dusts is much the most promising.

*Sticky bands.*—Many insects which affect stored products may be partially controlled, or may at least have their movements restricted, by the use of sticky substances, applied in a band to the walls or floors of storage buildings. Such substances are similar to those used for banding fruit trees. These sticky bands are of particular use when dealing with migrating caterpillars. They are also of use in isolating infested piles of goods. For such purpose, the bands may be applied to the floor.

It is important to remember that in dusty buildings the surfaces of the bands will rapidly become coated and may thus allow insects to pass over without becoming trapped. Care should be taken to ensure that the sticky surface is maintained in a fresh condition.

Commercial forms of adhesive for grease-banding of trees and banding of warehouse walls are available, but it is quite probable that bird-lime may be readily procured or made. The making and use of it is prohibited in some countries for bird-liming, but doubtless knowledge of its manufacture and use still persists.

## THE STORAGE OF ROOT CROPS

The storage of tropical root crops in a fresh condition is a more difficult problem than the storage of grain owing to the large amount of water they contain. There is a marked difference however in the case of storage of different kinds of produce. Thus yams are comparatively easily stored, while it is practically impossible to store cassava satisfactorily for any length of time once the roots have been dug.

The most satisfactory method of storage of sweet potatoes and cassava when the preservation of considerable quantities of such products is involved is to slice them and to convert them into dried chips. Slicing into pieces about half an inch thick, with or without peeling, and drying the slices in the sun by exposure on a drying floor is a common practice in parts of Africa. The process presents no difficulty except that the slices require to be protected from rain during drying since if they are wetted they are liable to become leathery and an unsatisfactory product results. Chipped or sliced root crops can be stored in the same way as dried grains and the same precautions require to be observed, as they are equally liable to become damaged by insect attack or mould growth.

*Yams.*—For storage in a fresh condition it is important that the tubers should be fully ripe before they are lifted. They are ready for digging when the foliage has become dry. So long as dry weather persists the tubers can be left in the ground, as is common in parts of West Africa, and lifted as required for consumption, but the usual practice is to harvest the yam crop as soon as it is ripe. The tubers should be dug very carefully so as to avoid bruising, as bruised tubers do not store well. After lifting, the tubers should be left exposed to the air for a few hours and then stored on shelves in a well ventilated and cool shaded room or store in layers three or four feet deep. Yams are also stored in carefully packed heaps within weather-proof buildings and sometimes in pits. The latter method cannot, however, be recommended unless the soil is thoroughly dry and likely to remain so.

Buds and eyes should be removed as soon as they show signs of sprouting, while bruised tubers are liable to attack by moulds, and if not removed they should be treated with slaked lime to prevent spread of infection. Under all conditions of storage yams require to be regularly inspected to ensure the removal of all diseased tubers, otherwise infection will spread rapidly, resulting in considerable loss. Under favourable conditions yams can be held in storage for several months, some varieties being much more suitable for lengthy periods of storage than others.

*Cassava.*—Cassava roots do not store well for any length of time after they have been removed from the ground. Under certain climatic conditions it is dangerous to attempt to do so. The crop can, however, particularly in dry areas, be allowed to remain in the ground for several months before deterioration sets in and the most satisfactory method of storing in a fresh condition is to allow the crop to remain in the ground, digging supplies as required for immediate consumption. Certain varieties of cassava can be left undug for much longer periods than others without undue detriment to the starch content of the tuberous roots.

Cassava lends itself very well to the preparation of dried chips and if for any reason it is impracticable to leave the crop in the ground this is the best procedure. In wet districts or in areas liable to insufficient drainage, cassava cannot be satisfactorily left undug, and if production is in exess of consumption needs the surplus should be converted into chips or meal. When the chips are required for use they may be pounded and sieved to remove the fibre from the meal.

Cassava meal may also be prepared directly from the fresh cassava, as is the usual practice amongst the aboriginal Indians in British Guiana and the Mayas in British Honduras. In the former colony, the roots are cleaned and then grated upon what resembles an English grater which has been beaten out flat and nailed to a small piece of board. The resulting meal is then stuffed into a basket-like cylinder which has loops attached to either end. One of these loops is attached to a beam in the house, whilst through the lower loop is passed a stout stick which is pulled upon so that the wicker cylinder, owing to the pressure, gradually becomes longer and longer. The watery contents so expressed are collected and boiled to form the cassareap which is used for the preservation of meat. The meal remaining in the cylinder is then taken out and rubbed through a sifter. It is then either dried in the sun or baked into thin cakes on large flat iron plates. Cassava meal and cakes form an important item of the diet of the Indian tribes of tropical South America.

*Sweet potatoes.*—Considerable attention has been given to the storage of sweet potatoes in the United States of America, and a technique of storage which has apparently given satisfactory results has been evolved there. [7] The essential points of the process are a preliminary curing process of ten days to two weeks duration at a temperature of 80° to 85° F., followed by storage in specially constructed stores at a temperature of 55° F. Such conditions are, however, unattainable under normal conditions in the tropics. Various methods have been attempted under tropical conditions and storage in pits or clamps has on the whole given the best results. In some recent trials in Barbados, the clamps were prepared by digging out the soil to make a shallow circular depression 3–4 inches deep and about 3 feet in diameter. The potatoes were stacked in this in a conical heap. The heap of potatoes was then covered with trash and a layer of soil placed over the trash. This method of storage was considered to be very successful, and to be quite practicable in areas where pests affecting sweet potato tubers are not prevalent. [8]

Results in Trinidad have also shown that under suitable conditions sweet potatoes can be stored in this way for about two months in fairly good condition with a loss in weight of about 15 per cent.

Some varieties keep very much better than others, and it is generally held that the red-skinned types are to be preferred for storage to the white or yellow skinned types. The sweet potato, known in Trinidad as Black Rock, has a reputation for storage purposes.

In storing sweet potatoes care has to be taken to protect the skin from injury by bruising or cutting, as the skin is very delicate and if it sustains injury decay spreads rapidly.


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