IMPROVED STORAGE STRUCTURES FOR THE PRESERVATION OF FOOD

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ABSTRACT: Structures for storing bagged grain and other agricultural commodities in developing countries in the tropics are discussed and desirable design features are listed. Design and operating procedures for improving the internal environment of storage buildings in hot/dry climates are considered and two examples of buildings designed to provide a low internal relative humidity in hot/humid climates are described. Some of the problems in the construction and use of fumigable stores are discussed in relation to two designs used in Nigeria and Kenya. There is a need for more published information on the design and use of such stores.

Factors affecting the choice of structures for storing reserve grain stocks in tropical developing countries are considered. The advantages and limitations of large airtight underground storage pits as used in Argentina and Kenya, and the conditions for their successful application, are reviewed. It is concluded that provision of additional storage capacity for reserve stocks is best made by building additional stores for bagged grain, if possible fumigable stores. Methods for providing additional protection against infestation of stocks in non-fumigable stores are mentioned.

INTRODUCTION: Rather than attempt to cover improvements in the whole range of storage structures, for bagged or bulk commodities, from farm to port silo, in all climates, it is proposed to discuss only structures to store marketed grain (and other agricultural products) in developing countries in the tropics. The structures discussed will be mainly buildings (warehouses, godowns) since storage, transport and handling of grain in these countries is still predominantly in bag, in spite of many attempts to introduce bulk installations. The fallacy that bulk installations *per se* will solve the storage problems of developing countries is largely, though not entirely, exploded; it is now recognised that many other changes, in agriculture, marketing and infrastructure, must occur before a change from bag to bulk storage is made.

Structures for storage of reserve or buffer grain stocks, which normally will be stored for longer periods than normal marketed supplies, will also be considered. Here the case for bulk storage of a particular type appears to be stronger and the arguments for and against such structures will be discussed - again in relation to tropical developing countries.

DESIGN OF STORAGE BUILDINGS: It is now generally recognised that a building to store bagged grain in hot countries requires design features not normally found in an industrial warehouse. These features, which aim to keep the grain as cool as possible, to maintain its moisture content at a desired level and to facilitate pest control, have been described and codified (see, for example, [1], [2], [3], [4] but are still sometimes omitted, for reasons of economy or ignorance. The main features may be listed briefly, before discussing particular points of interest and recent developments:

- heat gain from solar radiation is minimized by correct orientation (long axis E-W); by providing and maintain-reflective surface on walls and roof; by minimising window areas and avoiding roof-lights; and by shading windows, ventilation openings and walls as far as possible;

- ample ventilation is provided, but all ventilation openings should be sealable and screened to exclude birds and rodents;

- the floor is raised above ground level and incorporates a water-vapour barrier; floor and wall surfaces are smooth and free from cracks, crevices and ledges;

- doors are large, are fitted on opposite ends or sides of the building and fit closely to exclude rodents.

The improvement in internal environment of a building in a hot dry climate has been studied by Danby[5] in the Sudan, mainly in relation to housing but the same considerations apply to storage buildings. By excluding solar radiation and ventilating only at night a much lower and more uniform internal temperature may be maintained.

In a hot humid climate, with a low diurnal temperature range and high ambient relative humidity at night, ventilation is possible only in a limited period during the day. An example of the use of this technique to maintain a "safe" storage relative humidity of 70% is given in the design of a store for cocoa, erected in Ivory Coast[6].

> "The store covers half an acre and has a capacity of 5-6,000 tons of cocoa, stored in bags. The entire building, including the roof, is made up of two layers of concrete interlined with glass fibre. Natural ventilation is kept to a minimum, the doors being opened for only a few hours a day, at times calculated to coincide with minimum ambient relative humidity. These factors, allied to the size of the building, reduce the effect of ambient temperature and humidity variations, and provide the necessary conditions for maintaining cocoa at a moisture content not exceeding 7.5 per cent. It is claimed that cocoa, taken into store at 9 per cent moisture content, will reduce to 7.5 per cent during storage."

In this design a stable and favourable internal environment is evidently achieved by a combination of insulation and controlled ventilation but it would seem that mean internal temperature, and hence product temperature, must be higher than in a conventional store.

In another design for coffee storage in Madagascar[7] solar heating was used with mechanical ventilation to maintain internal relative humidity at a desired value. Product temperatures are not quoted, but since the ventilating air (applied between 8.0 a.m. and 5.0 p.m.) was heated up to 20°C above ambient, it would seem that at least some of the product was at a higher temperature than in a normal store.

The advantages of making a store sufficiently gas-tight to allow fumigation of the whole structure and its contents are well known; the additional expense involved has, however, limited the construction of such fumigable stores in developing countries. Two examples may be quoted, which illustrate different approaches to the design problems. In Lagos, Nigeria, cocoa stores with a total capacity of 90,000 tons were built in units of 2,500 tons. Each unit was in effect a concrete box with a shell concrete roof, fitted with a fan-assisted vertical ventilation duct for rapid evacuation of gas after fumigation was complete. Successful use is reported[8]. In Kenya stores of more conventional design with a sheeted roof were fitted with a hardboard ceiling. The roof space was ventilated. Double glazed non-opening windows were fitted just below eaves level. The walls were of hollow concrete block faced on both sides with a thin layer of cement/sand plaster. Two technical problems were encountered in the use of these stores [9]. The walls were permeable and required a gas-proof coating; and when the store was left sealed after fumigation, condensation occurred on the store fabric and the grain stacks. Installation of sealable extractor fans was recommended. It is understood that these stores are no longer used as fumigable stores.

Further development of fumigable stores of reasonable cost seems warranted. Little published information on the detailed design of such stores is available. Some recommendations on improving the gas-tightness of agricultural buildings have recently been made[10]

STRUCTURES FOR RESERVE GRAIN STOCKS: There is considerable current interest in the establishment, financing, location and management of reserve grain stocks. Several levels are being considered - international, regional and national - and the functions of such stocks are being variously defined and described as, for example, buffer, price stablization, famine reserve, food security, strategic, contingency, carry-over, emergency or disaster relief stocks. In the context of tropical developing countries two main cases can be distinguished: countries normally self-sufficient, where the need is to carry over stocks from surplus years to provide for deficit years; and countries normally importing part of their supplies, where a contingency stock is needed to cater for emergencies however caused (e.g. interrupted deliveries, natural disasters). In both cases it is expected or hoped that withdrawals from such stocks will be at intervals of two to five years and a policy decision is necessary on whether the same grain is to be stored for this period; whether the stocks are to be turned over at fixed intervals of, say, two or three years; or whether the stocks should be integrated with normal "commercial" stocks and turned over annually. (National reserve stocks are normally held by statutory marketing boards which also handle commercial stocks.) The decision does not depend only on technical (storage) considerations but the policy-maker needs to know whether structures and techniques are available which allow long-term storage with negligible loss of weight and quality.

The advantages of airtight storage for this purpose have recently been reviewed, and the large-scale underground structures used in Argentina and Kenya described by their designers[11]. The Kenya "Cyprus" bins have now been used for about six years and Baker[12] has reported on their perforance. In both Argentina and Kenya it has been shown that provided grain is dry and clean (dust-free) when stored, it can be stored successfully without significant insect or mould damage for at least three years. Great care is needed during construction to ensure that the concrete pit and roof are airtight and watertight, and the water table at the site must be well below the bottom of the pit. Another conclusion in both countries is that such pits are operated most efficiently when they are built alongside a fully mechanized bulk storage (silo) installation, with a normal range of cleaning and drying equipment.

In the countries under consideration silos, if used at all, are sited at ports or adjacent to flour mills. As mentioned earlier, internal movement and storage is in bag. It is probable, therefore, that only in the case of new silos could the addition of underground pits be considered and then only if a suitable site with a low water table is available. The location of new stores for reserve stocks is important, particularly when they are intended to absorb surplus stocks which may arise in different parts of a country from year to year. In some countries certain locations may be more favourable climatically than others for long-term storage. In each country a detailed study of grain production, marketing and storage conditions is necessary before new stores are sited.

It is concluded that in most developing tropical countries, provision of additional storage capacity for reserve stocks is best made by building additional stores for bagged grain, to the highest standard that finance allows. Thus, the reserve stocks become part of the total stocks held by the statutory authority, representing in practical terms and for control purposes the minimum stock level which must be held at any time in the year. Stock rotation and optimum storage capacity utilization are facilitated and the multi-purpose use possible with storage buildings allow storage of a wide range of commodities if necessary.

In a study[13] on reserve stock facilities for Senegal, Pattinson, after visiting airtight stores in Argentina and Kenya, recommended the construction of fumigable warehouses. Such warehouses could be constructed in such a way that they could in future be used for bulk storage of certain products if necessary.

Where reserve stocks are stored in non-fumigable warehouses, it may be considered worthwhile to provide additional protection against infestation by covering stacks with porous or plastic sheets[14] or even sealing stacks hermetically[15]. In the case of stocks supplied and replenished under food aid arrangements, it may in the future be possible to have grain specially packaged for long-term storage, for example by the Carbon Dioxide Exchange Method (CEM) of skin packaging developed in Japan[16].

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