WHERE IS CA STORAGE GOING IN DEVELOPING COUNTRIES?

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ABSTRACT

The paper considers the possibilities for CA grain storage in developing countries. The efficiency of current and traditional storage systems on farms and at national level are reviewed. Traditional unimproved farm stores are found to be generally efficient with low losses; On more developed farms losses are higher, but except in underground pits and where metal containers are used, it is considered more practical to improve conventional storage practices than to attempt to introduce an alternative system. Losses in national storage systems are variable and it has proved difficult to sustain an improvement in conventional store management to contain losses. Storage practices which were satisfactory for short periods are proving unsatisfactory for long term storage. Increasing resistance to insecticides and fumigants is causing concern although simple trials using inert gas as disinfestants are proving successful. Suggestions are made for the implementation and design of CA storage at national level and for regional reserve stocks.

INTRODUCTION

The storage of grain to provide a continuous supply of food between harvests has been practised for as long as cereal grains have been cultivated. The methods of storage adopted in any particular location would, no doubt, have evolved from trial and error methods using locally available resources and the indigenous skills of the farmer. It is claimed that underground storage has been an important method for storage of grains, if not one of the principle methods, in the main cereal growing societies for upwards of 9000 years (Gilman & Boxall, 1979). It is also suggested that in Roman times airtightness in underground storage was identified as a significant factor in grain preservation, although it is probably not until the early 19th Century that this fact was generally accepted (Sigant, 1981). Clearly, therefore, some form of controlled atmosphere has been practised for several millenia in what must have been, for the period, advanced societies, but without the appendages of modern technology.

In most developed countries, underground storage is not practised today, probably because agriculture has adopted new concepts of storage containers and mechanical handling from industry which are better adapted to above ground storage. Nevertheless, modern storage structures have been used for many years to provide airtight storage on a large scale. Recent developments in using modified atmospheric gas concentrations for the control of stored products insects and undesirable microbiological development is clearly a natural progression from airtight storage.

The paper attempts to formulate possibilities for the application of controlled atmosphere storage in developing countries as a continuing process of development and progression to meet the changing circumstances of food grain storage. To do so it is necessary first to examine the situation in these countries at the present time with respect to grain production, movement and storage.

The total food grain production in developing countries is a little short of 500 million tonnes. Only a small proportion of this leaves the farm for marketing. Various estimates suggest that around 75% or about 300 million tonnes will remain on farms or within small communities for local domestic consumption; 120 million tonnes pass into national marketing systems, the great majority being operated by parastatal organisations. Food production in developing countries is generally inadequate to meet requirements and the gross import of food grains into deficit countries reached 105 million tonnes in 1981. (There were exports of about 30 million tonnes, principally from Latin America.)

Looking to the future, FAO has calculated population, production demand and per caput production trends up to AD 2000 (FAO 1981). In Africa and the Near East, demand will rise at a faster rate than production, requiring continually increased imports. In other areas, demand and production is calculated to rise in line with each other. The implication of these predictions is that developing countries will probably increase their dependence upon imports of food grains, either as direct purchases or as food aid.

The situation is, therefore; that farming communities retain about 370 million tonnes for their own consumption; 225 million tonnes of home produced and imported grains are handled, stored and marketed to both rural and urban populations, largely by national parastatal organisations; these amounts are likely to increase during this and the next decade. The need and the potential for the development of efficient and effective storage systems is very considerable.

FARMER STORAGE SYSTEMS

Farmers' storage systems are extremely diverse. They are developed largely through the interaction of the climate, the agricultural system, and the availability of local resources. Farmers in dry areas are considered to have fewer storage problems than those in wetter and more humid areas where storage must be preceded by a drying period, or the storage system must incorporate a facility to dry. Conversely, farmers in dry areas have only one crop each year (unless multicropping with irrigation) and have to store for 11 months while farmers in more humid climates generally have a range of alternative food crops, frequently have two crops each year and therefore need to store grains for only 4-5 months.

There are, however, essential common elements in all farmers' situations:

(a) Credit or investment in improvements is often expensive and there is competition for improvements and development throughout the farming system;
(b) There is also competition for the farmers' own managerial capabilities and undue emphasis on changes in one sector of the farming programme may distort attention away from other and equally important sectors;
(c) Although there are well recorded exceptions, farmers are generally given poor support by extension services in the post-harvest sector. The Service itself may be sparse, poorly organised, but generally extension workers' education and training has been directed towards crop production and crop preservation has been neglected;
(d) The difficulty of maintaining inputs into the farming system. Insecticides provides a classical example; insecticides are frequently proven to be effective for a particular situation but the cost and the organisation to pack, distribute and monitor the insecticide is too costly for a commercial operation and beyond the capability of the local resources. (McCullum Deighton, 1981).

The efficiency of farmers' storage systems has been given much consideration recently. Reliable data on farmers' storage losses are very sparse except where specific situations have been identified. Many of the estimates of physical loss are based on experimental work in laboratories or small scale field trials which are extrapolated to what are believed to be normal post-harvest practices. Frequently the figures quoted are either an upper extreme or an unqualified average. Whilst there is little justification for using this data to determine the need for remedial measures to reduce losses they have, however, drawn attention to the variety of losses that can occur and how these can be measured. Direct weight loss is the simplest, the one most amenable to measurement and the kind of loss most often quoted.

The FAO Prevention of Food Losses Programme has established that the general levels of total post harvest losses on farms of staple foods such as cereals is around 12% (Huysmans, 1982). Detailed studies have indicated that in traditional farming systems using unimproved varieties of cereals, storage losses can be as low as 3% (Greeley, 1980) and are generally in the range 5-8%. It can be argued that at this level of loss the resources needed to reduce these losses even further may be more effectively employed in other sectors of the farming system. Losses are known to be higher when so-called improvements are introduced into the traditional system, of which multicropping with irrigation and new high yielding varieties are the most significant. Nevertheless Golob (1981) found that in well managed farmers' stores the use of insecticides to prevent loss did not yield an economic return when storing hybrid high yielding varieties of maize.

Most losses so far discussed are caused by insects but losses also arise from storage at too high moisture contents which are much more difficult to quantify. Drying of crops at farm level is a most intransigent problem. Considerable resources have been expended on the development of farmers' drying systems with remarkably little result. Where it can be practised, sun drying is quick and effective, but elsewhere the most promising developments are those based on traditional air drying systems which require exposure of the crop to ambient air for several weeks or months.

Attempts have been made to improve farmers' storage including the use of plastic liners for the ubiquitous gunny bag to provide a gas tight container for fumigation by liquid fumigants, concrete structures for ventilated and airtight storage, and small flexible silos for airtight storage (O'Dowd, 1971). Rarely are these improvements acceptable or sustained once the initial enthusiasm for them has waned or the Government or donor financial support has been removed (Andrews, 1973). Connell (1974) comments that it is extremely difficult to develop a satisfactory economic argument in favour of action in attempting to solve a stored product insect pest problem. It can be very difficult to persuade a farmer to seek credit for insecticides or other inputs, particularly for grain to be marketed, if he is not to be penalised for a modest infestation or be given a bonus for maintaining grain in good condition.

For this reason there seems little prospect or indeed incentive in the forseeable future, to attempt anything more sophisticated for above ground storage systems than to ensure that the traditional systems are properly managed and modified as necessary to accommodate changes in farming systems, improvements in the flow of agricultural inputs and developing technology.

Underground or pit storage occupies a somewhat anomalous position. It is traditional in many areas (Gilman and Boxall, 1974) and whilst performance is somewhat variable it can, as airtight storage, provide an effective protection against insects and rodents over long periods. There have been a number of instances when attempts have been made to reintroduce pits in some areas, but the general impression seems to be that underground storage is on the decline, albeit slowly. It may be speculated that this is due to the greater need for drying newer varieties, the improvement of resources for building above ground stores and distributing agricultural inputs, including insecticides; and also because of an increasing antipathy towards the labour needed to build and empty pits. It is a system clearly appropriate to the drier areas where rainfall is erratic and where there may be a need to store food for several seasons as a precaution against crop failure. The depletion of oxygen is, however, alleged to be closely associated with soil moisture, which moves into the grain from the surrounding soil. Mould damage to grain adjacent to the pit sides and on the surface of the grain bulk is, therefore, to be expected. Efforts have been made to line traditional storage pits but none of the methods adopted appear to entirely exclude moisture. In Ethiopia, where underground storage is well established in some areas and where losses due to water damage can be considerable, waterproof concrete liners have been introduced into traditional pits with some success and this improvement appears to have been welcomed by local farmers (Boxall, 1973).

Metal bins have developed recently as non traditional farmers' storage structures in Southern Africa and parts of Central and Southern America. In Africa particularly, they were adapted from water tanks, the manufacture of which had developed as a significant industry. Because of this, the bins were relatively cheap compared to traditional stores. Additionally, they prevented rodent infestation and reduced exposure to insect infestation. Pre-drying of produce is essential if moisture damage is to be prevented. In well managed stores, insecticide is used and there is apparently a concept of using the bins as airtight storage (Giles 1983). However, the method and standard of manufacture are frequently inadequate to ensure air tightness. Fumigation of metal bins using phosphine is practised occasionally and appears satisfactory but there are no reports of the CT products attained.

In both improved pits and metal bins there is a possibility of improving storage conditions by using some form of controlled atmosphere at least as a disinfestation measure. The efficiency of the present systems will, however, offer significant competition to any alternatives until they are found to be inadequate or insects become resistant to the commonly available insecticides.

LARGE SCALE STORAGE

The storage functions of Government and parastatal marketing organisations include:

1. Storage of seasonal or operational stocks to meet seasonal demand and effect price stabilisation;

2. Maintenance of carry-over stocks between seasons;

3. The establishment and maintenance of strategic or longterm reserves against crop failures.

In all these operations, it is generally the marketing policy of Government which determines the scope and scale of the storage operation. Seasonal and carry-over storage involves the aggregation of locally procured produce into stores holding upwards of 1000 tonnes and storing for periods of up to twelve months for the majority of grain, but frequently for periods of up to 24 months. Heretofore, storage management has relied on good storage hygiene and the use of insecticides and fumigants to control insect infestation. Spoilage by moisture is not usually serious, largely because Government purchasing is limited to maximum moisture content standards, but the increasingly frequent reports of the incidence of toxins in stored products suggests that moisture content problems may be under-estimated.

The efficiency of these storage operations has not been given serious study, although it is known to vary widely, ranging from very good with very small losses, to very poor with almost total loss of stored commodities, at the two extremes. It is self evident that sound informed management is essential at all levels, supported by clear policies, adequate budgetary provisions for store maintenance and consumables and adequate training facilities for operational staff. Regrettably, it is all too common for some if not all of these requirements not to be met. In a survey of the use of flexible storage structures, O'Dowd and Kenneford (1983) found that unacceptable performance was largely a fault of the human factor rather than any fault in the structures themselves. An informal evaluation of the experiences of trainees at Tropical Products Institute suggests that the principal difficulty they face in applying improved storage practices is the unawareness of their immediate managers or the constraints placed on them by the unawareness of higher management or by the impedence of cumbersome and inflexible administrations.

An indeterminate proportion, but probably exceeding 95% of the grain, is stored in developing countries in bags. The stores themselves are generally of a conventional but quite variable warehouse design, ranging in size from 500 tonnes upwards. Design requirements are generally simple (Gracey and Calverley, 1979; Hayward, 1981). In spite of this, it is very difficult to ensure that stores are constructed to reasonable standards, not necessarily to the rigid costs of building practice current in developed countries but to standards that ensure the building is sound and will remain so during its operational life. Gracey (1981) outlines avoidable problems in the construction of new storage facilities and suggests that the rapid development of a modern storage system may overload the limited managerial resources of a developing country. Because of this there is a lack of attention to detail that ultimately results in serious deficiencies in the completed building; causing rapid deterioration and high maintenance requirements. Such defects have been noted by Gilman (1982) in buildings used for long-term storage in the Sahel.

The advantages of building stores sufficiently gas-tight for fumigation of the store and its contents have been appreciated for some time but the additional expenses for purpose-built stores have limited this development. Exceptionally, cocoa stores at Ikeja, Nigeria, with a total capacity of 90,000 tonnes, were built as gas-proof stores and are reputedly very sucessful (Riley and Simmons, 1967). In Kenya, stores of a more conventional design were adapted for fumigation by installing a ceiling, fitting non-operable windows and lining the walls. In practice these stores did not perform well and there has been no attempt to pursue this development. Elsewhere the simplicity of total store fumigation and, in some instances, its lower cost than other methods of disinfestation (Gilman, 1982) have led others to attempt this practise but with limited success and a failure to control insect pests (Champ and Winks, 1982). Taylor (1982) and Tyler *et al* (1982) investigated total store fumigation in Senegal and Bangladesh and in all cases noted that fumigants leaked rapidly through the porous brick and plaster walls of older stores. Modern, well constructed and better sealed stores provided better gas retention but this was less good than treatments applied under sheeted stacks within stores. This inadequate treatment has led directly to insects becoming resistant to phosphine and able to survive treatment.

There are some bulk handling installations in developing countries. These are to be found in some port installations and associated with processing industries. Generally, however, there are far too few of them and the units are too widely scattered to establish a national bulk handling system. Some authorities conclude that these installations are not fully exploited because the necessary infrastructure does not exist (Baehr, 1982). Nevertheless, there have been some successful bulk stores, designed and built primarily for long term airtight storage. Lopez (1973) describes the airtight underground stores in Argentina. He comments that many such silos are no longer airtight but give better storage conditions than above ground silos because of better thermal characteristics. Semi-underground air-tight stores in Cyprus and Kenya (the so-called Cyprus Bins) have not been without problems (De Lima, 1981), but have successfully stored wheat and maize for long periods.

Flexible walled sealed silos ("Butyl Silos") have also been used satisfactorily to store grain for relatively long periods. Insect infestation was well controlled whilst the airtightness of the fabric was maintained. This, however, required exacting standards of site management which was often not available and the silos have been found in practice to have a relatively short life (O'Dowd and Kenneford, 1983).

THE APPLICATION OF CA IN DEVELOPING COUNTRIES

There are compelling reasons why we should continue to monitor current storage practises and pest control problems. There is evidence that significant changes are taking place in farming practices; the extended use of irrigation; new breeds of cereal grains that have different, usually inferior, storage characteristics. More farmers are growing larger crops and storage practices, satisfactory for subsistence farmers' domestic requirements, may not be suitable for a significant marketable surplus. National marketing organisations are finding that its storage operations which were satisfactory for several months storage are inadequate when the storage period is extended into a year or more.

If current generally accepted recommendations on good storage practice and pest control operations were put into practice, there would be a most significant reduction of storage losses. Whilst historical evidence suggests that because of considerable inertia and resistance to change, this can never come about through the application of different operations and procedures, this should not deter a continued and sustained effort to improve present storage practices and encourage their adoption as far as possible.

Meanwhile, pest infestation problems continue to present themselves in different ways. Resistance to insecticides is now widespread involving all major pesticides and most of the important pests of cereal and cereal product storage (Champ, 1978). Control failures in the field have been unequivocally associated with resistance and have forced the use of some insecticides to be abandoned in some areas. With the now proven occurrence of significant resistance to phosphine in the field, Tyler et al (1982) suggest that the effectiveness of phosphine disinfestation procedures require close examination and in particular that phosphine fumigation should not be used as a palliative treatment. The translocation of pests to regions where there are no predators or natural checks raises particular and difficult problems of control (Golob and Hodges, 1982). Equally important, the longer periods of storage raise problems of the preservation of quality without increasing chemical residues to unacceptable levels.

There is no single solution to these problems and CA storage is likely to be one of the alternatives that can be applied as appropriate to a particular situation. The particular advantages of this system have been described at an earlier Symposium. Apart from extending simple airtight storage, CA storage is unlikely to have any application to farmers' storage systems, because the benefits to be gained are insufficient to justify the very considerable effort needed to establish and maintain a system requiring such a level of technology.

A modified form of C.A. storage has been shown to be effective for the storage of milled rice in Indonesia. Stacks of 200 tonnes were covered with transparent plastic sheets and sealed. CO_2 was introduced as a fumigant gas after evacuating the air with a vacuum pump. After eight months storage there were no living insects visible through the plastic sheet and the quality of the rice has been found to be unchanged. No data is available on the levels of CO_2 established in the stack and for how long these were maintained. The trials continue. Costs of the system are not available but it is reported to be considerably more than a single fumigation with phosphine and it is therefore more suited to longer term storage.

The apparent success of these trials warrants further study and similar development trials could be carried out wherever there are locally available supplies of insert gas, and an organisation capable of carrying out scientific work of this nature.

The establishment of a CA storage in purpose built, or modified stores, with continuously maintained levels of atmospheric gases as described by Banks and Annis (1980) has, *prima facie*, little advantage over seasonal bag storage systems in developing countries where in most cases absolute control of insects is not essential. It is more important to ensure that losses during and arising from the storage period, are contained within economic or otherwise acceptable levels. Costs are difficult to apply generally, for example the cost of a store building in Tanzania is approximately twice the cost of its equivalent in Kenya; in Mali it is more than three times and in Nepal more than five times.

Costs analysis are therefore likely to be very location specific. Donor organisations contribute a substantial proportion of the investment in grain storage facilities and, since it is highly probable any CA storage development in a developing country will be similarly aided, some form of cost benefit analysis of the system will be required.

A decision to establish a CA system would requir~, in the first instance, a clear identification of an appropriate situation where its particular advantages could be fully exploited. It will also need a firm commitment by both Government and donor to the project as, in the first instance, a development project. The problems of construction, management and supporting organisation which are all too frequently encountered in the development of storage facilities and which have already been referred to, need to be recognised from the outset and a strategy developed to ensure they are avoided or at least mitigated. The project will almost certainly require strong managerial and technical support from Government and donors for significantly longer than is customary with grain storage projects and the timescale should be measured by the attainment of a successfully operating and self sustaining commercial operation.

There are a number of design parameters which should also be considered in addition to general design requirements outlined by de Lima (1980b) and Banks and Annis (1980).

Function

It would be prudent to design stores so that if needed they could be used successfully with more conventional bag storage systems. This would include making provision for ventilators in those areas where they would normally be recommended, providing storekeepers' offices and provision for a fumigable store for bags and a store for chemicals.

Size

Transport to and from storage sites is frequently very difficult to organise properly and rates of grain movement are often below expectation. This has consequences in the time taken to fill and empty stores during which time protection for the grain will be reduced. Individual stores should therefore not exceed 5,000 tonnes capacity.

Acceptable Moisture Contents

A survey on flexible sealed silos ("Butyl Silos") indicated clearly that the principal cause of failure was storing at too high a moisture in conditions which did not permit ventilation or the removal of moisture from the grain by diffusion or along vapour pressure gradients. Some ventilation of CA stores is inevitable through leakage and the balancing of atmospheric pressures, but it should be clearly established for each crop and locality what maximum moisture contents would be tolerable.

The World Food Council and other UN agencies have outlined a number of proposals for the establishment of regional grain reserves in chronically grain deficient areas to avoid the hasty and often expensive arrangements for contingency aid when famine is imminent. There are many practical difficulties in such proposals, including in particular the difficulty of recycling stocks through national markets without disturbing normal marketing operations. The capability to maintain stocks in sound condition in many instances in a hot, and therefore hostile, environment over long periods, is an obvious requirement, and one that could be satisfied by CA storage. Reserve stores would need to be under international management and the problems of ensuring adequate technical and management support should be more easily dealt with. In such a situation the alternatives of bag and bulk storage and, if bulk, what form the structures should take, are legion. It is important that all alternatives are fully explored and that new ideas are not rejected simply because they are novel. The choice will be decided on political and financial as well as technical grounds and these must ensure that the system which is selected should be feasible, economical and meets the needs of people for whose benefit it is intended.

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