FINAL TECHNICAL REPORT

CPHP project R6502
Mud based silos – farm stores for cereals
1999

Brice, JR[1]; Devereau, A[1] and Tran, B[1]

NRI Report No. 2453

[1] Natural Resources Institute, Central Avenue, Chatham Maritime, Kent ME4 4TB.

EXECUTIVE SUMMARY

This project examined the Bimoba design of mud silo being extended by the Ministry of Food and Agriculture throughout the Northern Region of Ghana. The basic type of store was found to be a cheap, environmentally sustainable store for cereals (**Output 1**).

Of the three aspects examined when determining the store's suitability for storage purposes (technical effectiveness, affordability, and sustainability), the following key points were identified:

- Farmers expectations for the mud silo include issues such as flexibility, prevalence of building materials, durability, maintenance, secrecy, and effectiveness of chemicals, as well as storage performance. Of the 15 factors raised by farmers when deciding on the type of store to use, **protection against insects, number of crops that could be stored, and protection against termites were rated as being the most important.**

- Traditional timber-based structures were found to exhibit more rapid and greater changes in temperature and moisture content during storage, and to have lower overall temperatures and moisture contents than mud silos. Mud silos can be very effective stores although severe levels of moulding can occur (probably more than in some other more open types of store) if the grain has not been dried sufficiently. **Recommendations are therefore made that maize should be dried to around 11% for storage in mud silos (compared to 12% in timber-based stores).**

- Extremely high levels of aflatoxins were detected in grain samples at the beginning of storage (20 times the UK safe limit), raising very real health concerns. Although levels were found to fall in all types of stores, levels of *Aspergillus flavus* and aflatoxin fell less in the timber-based structures. **A further study of this aspect of storage is recommended.**

- The effectiveness of a number of treatments against termite attack, incorporating either physical barriers or the use of traditional/artificial chemicals, were tested at the research station. Although these treatments were then tested on-farm, a combination of factors meant that these results could not be confirmed. Given the extreme levels of damage caused by termites **strong recommendations are made to investigate the appropriateness/effectiveness of various potential termite-control measures more fully than was possible during this project.**

- The durability of mud trials showed that the incorporation of grass in the mud material is essential and that plastering (rendering) of the walls is highly effective in reducing the amount of maintenance required. However little or no beneficial effects of incorporating two extracts from local plant materials, as traditionally practised, were found.

- A Storage Structures Handbook was developed (using the findings from this project as well knowledge already available) to be used as a tool for researchers/advisors to identify the most suitable type of store for a variety of geographical and climatic conditions.

Mud silos, along with other traditional storage structures found in northern Ghana, are totally unsuitable for fumigation using phosphine gas (**Output 2**). Only by applying extremely strict procedures under experimental conditions can some (but not all) silos be sealed to a sufficient degree for fumigation purposes. This project therefore recommends, most strongly, that **all**

efforts must be made to dissuade farmers from using phosphine as a means of pest control, and that alternative methods of pest control must be promoted. Given the poor levels of gas-tightness capable of being achieved, CO_2 levels (due to respiration from the grain, and mycological and insect activity) were unable to reach the levels capable of reducing/eliminating insect growth.

Extension issues raised by farmers that need to be addressed include the expansion of mud silo building projects, training in building and maintenance skills, greater involvement of NGOs in programmes, and flexibility of inputs such as credit schemes.

CONTENTS

ACKNOWLEDGEMENTS

This project was performed in collaboration with the Savannah Agricultural Research Institute (SARI) at Nyangpala in the Northern region of Ghana. The authors would therefore like to thank the Director of SARI for allowing us to base many of the on-station trials at the institute. We would like to thank Dr Salifu for releasing his staff and facilities for use by the project. Of his staff we would like to thank in particular Mr Ayuba I Hussein for his dedication and commitment to the project throughout its duration.

Thanks also go to Director of Agriculture for the Northern Region and to his staff, in particular Mr Haruna Fuseini, for their invaluable advice and assistance in making this project possible.

The United Kingdom Department for International Development (DFID) Crop Post Harvest Programme funded the project. DFID have not formally reviewed this report and so the views expressed are not necessarily those of DFID.

Chapter 1

INTRODUCTION

Structures used for holding grain on the farm in rural communities are extremely diverse, no more so than in Ghana (see Annex 1). Their design and construction is based on economic, technical and social considerations. However, as crops change in type and quantity, these traditional store types often become inadequate, leading to deficiencies in their economic and technical value. This project was designed to address the procedures for developing an improved storage structure that can be applied to a wide range of circumstances.

The Project Purpose was "*Environmentally sustainable and safe post-harvest and pathogen control methods and procedures developed and promoted*". The two Projects Outputs were:

> *"Cheap, environmentally sustainable store for cereals produced"*, and
>
> *"Method for the safe and effective use of phosphine for small-scale applications developed"*.

Due to dwindling supplies of wood and the reduced area of sorghum grown (due to falling levels of soil fertility), the Ministry of Food and Agriculture (MoFA) have started to actively encourage the use of one particular design of mud store (the Bimoba) in place of stores built from timber and sorghum matting. Particular emphasis was therefore placed during this project on the comparison of the Bimoba design with the most common design of timber-based structure.

A participatory rural appraisal was performed at the beginning of the project to identify various technical and socio-economic aspects of post-harvest practices - the findings from this survey were then used to direct the project activities.

In relation to the first Output:

- the technical effectiveness of the two principal types of stores was assessed by monitoring conditions within the stores during two storage seasons (96/97 and 97/98).
- separate trials were established to identify suitable treatments against termite attack, as well as to assess the durability of mud materials.
- a storage structures handbook was produced to assist the reader in identifying the most cost-effective and suitable type of store for use in a variety of situations. This combined information gained from this project with information already available.

Although the second Output was valid at the time that the Project Memorandum was written, circumstances subsequently changed for two reasons:

- firstly the final results from the previous project A0419 “Improving the use of phosphine for small-scale fumigation of grain on farms in Ghana” (not previously available) indicated that it is extremely difficult/almost impossible to seal the Bimoba mud silo (or any other small-scale structure likely to be used for storage purposes in northern Ghana) even under controlled experimental conditions to such a standard as to be suitable for fumigation purposes;

- secondly, none of the farmers in the PRA survey mentioned the need to be able to seal a storage container for fumigation purposes as a factor considered when deciding on the type of structure to be used.

This second point may have been due to ignorance of the need to seal the stores or may have been due to the feeling that it was not necessary. Given the efforts by the Ministry of Food and Agriculture (MoFA) to educate farmers in the correct application of phosphine gas (MoFA Post Harvest Officer, pers.com.), this is a particularly worrying finding, and strengthens the argument that farmers should not be attempting to fumigate grain in their silos.

Partly as a result of these two points, and partly due to the need to increase the emphasis on identifying suitable treatments to protect small-scale storage structures against termite damage (as identified in the PRA survey performed in the first year of the project), it was decided to redirect efforts from the use of phosphine towards the protection of small-scale storage structures against termite attack. Fumigation activities in the project were therefore confined to two fumigation trials to check the validity of the findings from the previous project, and to assess whether there were any other surface treatments that may have been able to achieve sufficient levels of gas-tightness for fumigation purposes.

Chapter 2

SURVEYS

Two surveys were performed during the mud silos project:

1. A participatory rural appraisal assessing various technical and socio-economic aspects of post-harvest practices, constraints and opportunities (for cereals and legumes) within the three northern-most regions in Ghana.

2. A participatory study of the level of farmers' needs, and their preparedness to adopt and pay for mud silos. Particular attention was paid to identifying the factors that could influence the adoption of mud silos by farmers in Northern Region.

TECHNICAL AND SOCIO-ECONOMIC SURVEY, 1996

The survey was carried out throughout the Northern, Upper East and Upper West Regions of Ghana in July/August, 1996. As well as addressing factors concerned with the mud silos project, the survey also addressed issues concerning two other CPHP funded projects implemented by NRI in these regions – 'The use of plant materials for protecting farm stored grain against insect infestation' (R6501), and 'Improvement in the storage and marketing quality of grain legumes' (R6503).

Two teams, each with at least one scientist and one socio-economist (familiar with the technical content of the projects and PRA techniques respectively) surveyed a total of 23 villages in the three northern regions (Table A1.1 and Figure A1.1).

Both groups and individuals were interviewed in each village: where possible separate groups of men and women were selected since views of practices and constraints were often found to vary with gender. Following initial discussions with the village elders/chief, the farmers were divided into groups using the criteria 'length of storage practised by individual farmers'. Information was collected from each of these groups on specific aspects concerning each of the three projects. Where possible, individuals not included in these discussions were taken aside by another member of the team to act as potential case studies.

Results

Whilst storage issues were raised as problems in all villages, their ranking was lower than expected because of severe constraints in the quantity of produce that can be grown: primarily due to falling levels of soil fertility (hampered by the high cost and poor availability of fertilisers); and the general scarcity of affordable cultivation equipment (animal and tractor drawn equipment), coupled with the high cost of labour (Table 1). Quantities of commodities placed in storage are, therefore, generally lower than would be desired by farmers. It is clear that production and post-harvest projects need to go hand-in-hand to maximise the benefits from such research.

Table 1 Summary of agricultural constraints expressed by farmers in the 1996 PRA survey (in order of number of villages in which the factors were mentioned)

Constraint	Type	Number of Villages Mentioned	Regions where not mentioned[1]	Order of Ranking
Access to labour saving technology for land preparation[2]	P	13		2
Storage pests	S	13		12
Cost and/or availability of fertiliser	P	11		6
Uprooting of seeds by birds and rodents	P	11	UER	9
Marketing problems[3]	M	10	UER	8
Weeds[4]	P	8		7
Poor Rainfall[5]	P	7		11
Livestock diseases	P	4		10
General financial constraints		4	UER	13
Land fertility	P	3	UWR	=3
Seed availability and cost	P/S	3	UWR	=3
Food availability at planting time		2	UER,UWR	1
Monkeys/rodents eating crops in the field	P	3	UER,UWR	=3

Key: P = Production (Farming System) Constraint
S = Storage System Constraint
M = Marketing System Constraint

1 This column gives only a very crude indication of regional differences in priorities.
2 Usually either tractors or bullocks.
3 This includes: early sale; low prices; low bargaining power in relation to middlemen, and; transport problems.
4 Usually Striga.
5 This was mentioned in only one village in the NR where it was ranked 6th. It was ranked highest in the UWR.

All the farmers interviewed used storage structures, each farmer often using several different designs for different crops or storage periods. Many types of storage structure were found throughout the three regions (summarised in Table 2, full details in Annex 1).

Table 2 Principle storage structures used throughout northern Ghana

Code	Store Type	Other local names	Region	Description
A	**BIMOBA** mud silo 1	Bule, Lipil, Buga, Bugi	Northern	Spherical shape on three or four legs (as introduced by MoFA)
B	**BAARE** mud silo 2	Bui, Tula, Baari, Bood, Bwr	Upper East	Cone shaped, built on a layer of stones and/or poles. Free-standing outside of any other structure.
C	Mud silo 3	Katari, Bowr, Bowryari, Vuri	Northern	Square or circular, built within a room (or under a flat roof), tapering to a neck protruding through the roof (access via the roof)
D	Mud silo 4	Namvuri	Upper West	Usually rectangular, outside of the house, floor raised 0.5m above the ground (with fowls below), made from bricks, up to 3m tall.
E	Mud silo 5	Buo, Katanga, Bowrpla	Upper West	Small, often egg shaped, usually portable store. Often sealed at the top with a small opening in the side.
F	**KAMBONG** (wooden framed, thatched)	Kpacharaga, Chenchunkum, Chenchenlenkung, Napoo, Sigi, Brugu, Ganga, Pulu, Narpaug	mainly NR, but also UE and UW	Wooden frame work with 'Zana' matting (woven sorghum matting) floor and walls. Floor traditional ½m off the ground (MoFA 'improved' Kambong is raised 1½m above the ground for improved rodent resistance)
G	**LINGA** (raised platform)	Kikaafil, Capala	Northern	Platform made from wooden poles (often with matting from sorghum stalks), raised 1½ to 2 metres from the ground. Area underneath often used as a shaded meeting place.
H	Baskets: (i) **KUNCHUN** Unplastered	Chenchunkum, Napogu, Pege, Sampaa(?), Yikori, Koyonko, Naparg	all Regions	Basket made from sorghum stalks. Usually placed on a raised platform or Linga. The name usually describes the basket itself (which is then placed on a Linga) but occasionally the name indicates the entire structure (including the Linga). Sometimes there are separate names for those plastered with cow dung and those that aren't. Other times the same name is used whether or not it is plastered. Baskets usually plastered when storing smaller grains such as millet and sorghum (or for insect control?).
	(ii) Plastered	Chenchunkum, Pupuri, Kunchun (Kupong), Kosorgu, Yikori	mainly NR, but also UE and UW	
I	Fired clay pots	Singi, Simme, Dugu, Vijen, Dokoh, Yor (small), Duk (large)	all Regions	
J	Jute sacks		Northern	

Farmers were asked to list the factors they considered when comparing the suitability of each type of store. They were then asked to rank these factors in order of importance, with 1 being the most important. Of the 15 factors raised by farmers as needing consideration, the three most important factors were:

- protection against insects
- number of crops that could be held in the store
- protection against termites

Of the 10 broad types of structure identified, villagers were asked to score each type against 15 different storage factors (Table 3).

Table 3 Mean scores (0 = poor, 10 = excellent) of storage structures against the storage factors in order of importance (by ranking)

Factors	Ranking[1]	Store types (see Table 2)									
		A	B	C	D	E	F	G	H	I	J
Technical Effectiveness of the Structures:											
Protection against Insects	1.5	9.0	5.8				4.4	4.6	4.9	7.5	1.5
Protection against Termites	2.7	7.0	4.0						1.5	8.3	5.0
Protection against Rodents	3.1	8.6	5.0				2.5	2.8	4.9	7.0	5.5
Protection against Rain/water	3.4	9.8	6.0				6.5	2.0	4.2	8.5	4.0
Protection against Theft	4.1	8.7	10.0		3.0		3.6	3.7	3.4	5.8	1.7
Protection against Fire	5.0	10.0	9.0				3.3		2.0	10.0	3.0
Potential Constraints to the Adoption of Structures:											
No. of crops	2.5	9.2	8.0		5.0		7.6	3.0	2.0	8.0	7.5
Store capacity	3.5	6.3	10.0				7.0	7.0	1.7	3.0	2.0
Life of the store	3.6	9.6	8.4		7.0		3.4	1.3	3.0	8.3	3.3
Availability of materials	3.8	4.8	6.8				5.8	5.2	6.1	5.5	5.5
Ease of construction	3.9	5.0	6.3	6.3			6.1	8.0	5.1	6.7	0.7
Acceptability (ethnic?)	4.3	9.5	5.5	6.8			6.0	4.0	4.5	6.7	1.0
Cheapness of stores	4.6	4.7	4.5				5.1	7.7	3.6	6.4	4.0
Ease of use	5.0	4.0	4.3				5.6	7.5	5.7	8.3	5.5
Maintenance	-	10.0					2.0		2.0		
MEAN SCORES	**-**	***7.7***	***6.7***	***6.5***	***5.0***		***4.9***	***4.7***	***3.6***	***7.1***	***3.6***

[1] where 1 is the most important

Overall, in deciding which type of structure to use, farmers were particularly concerned about minimising damage to stored grains and legumes caused by insect, termite and rodent attack. In certain areas there were particular storage problems, for example termite damage to structures as well as to the grain was a problem especially in UER. Similarly, drying difficulties and high moisture content of stored produce also caused problems in some villages, possibly leading to the production of moulds during storage.

Of all the stores, the Bimoba mud silo (store A) was the least widely used. However, farmers who were using it, had seen it, or who had heard about its use, were impressed, and gave it high scores in terms of technical effectiveness (i.e. protection against insects, termites, rodents, water, and fire, Table 3). The more widely used Baare mud silo (store B) was given lower scores in terms of effectiveness by those farmers who had experience of it. Both types of mud silo scored considerably higher than the other three non-mud structures.

A wide variety of protection methods against insect attack, for grains and legumes, were encountered throughout the three regions. A total of 32 methods were identified: eight using inert materials (such as sand, ash, etc.); 19 using plant materials; and five using synthetic materials. Farmers perceptions of the effectiveness of different methods were found to vary considerably, making it difficult to assess the most effective. Actual methods used were strongly influenced by tribal customs (as was the case with storage structures and the types of legumes grown), often resulting in neighbouring tribal groups using totally different methods, usually with mixed results. A very real need was demonstrated for the testing of the effectiveness of specific methodologies, and recommendations were made to this effect (types of materials to be examined) for the plant materials project.

Legumes were found to be widely grown throughout the three regions. Whilst improved, higher yielding varieties are available in most of the areas, poor resistance to disease and insect attack, both pre- and post-harvest, means that their usage is limited. Several local varieties have been identified and project recommendations were made to assess their resistance to insect damage. Whilst insect damage in storage is undoubtedly a problem, other constraints, mainly financial, were identified as preventing long term storage. This had the effect of reducing the apparent pest control problems in some areas. However, if financial constraints can be reduced in the future, the quantities in, and the duration of, storage will be dramatically increased. Insect problems with the storage of legumes will then become severe if the problem is not addressed.

Conclusions

The field work suggests that the main constraints to the adoption of small mud silos in areas where non-mud structures are in use will be cost, difficulty of construction and, in certain areas, non or poor availability of materials. Although the silo was also not felt to be particularly easy to use (nor were several of the other designs), ease of use was not felt by farmers to be a particularly important criterion for adoption. Cost and ease of construction are both linked to the availability of trained personnel, which will be addressed as the use of the silos is extended by the MoFA. Research activities within the silo project into the suitability of different types of soil for the Bimoba silo (currently termite soil and grass is recommended), will address the problem of poor availability of materials.

On balance, the prognosis for the adoption of small mud silos, such as those of the Bimoba design, in the Western Dagbon area appears to be favourable, however, a number of issues will need to be addressed to enhance its uptake. In areas where non-mud silos are used, interventions could usefully focus on improving existing mud structures using the results from trials on the Bimoba silo. An example of this would be the treatment of mud structures to protect against termite attack - whilst such trials will use the Bimoba design mud silos, results will be transferable to other mud structures.[1]

Recommendations

Following the PRA survey, certain recommendations were made for mud silo project activities (other recommendations were also made with regards to projects R6501 and R6502 but these are not reported here):

1. It is essential to confirm whether mud silos of, or similar to, the Bimoba design, are the most suitable store design for further extension (examining potential moisture and temperature problems within the stores with regard to its storage characteristics and subsequent development of insect and mould problems) and whether the design needs to be modified in any way.

2. Given the concerns raised over termite damage to structures and the grain contained within, methods of reducing termite attack (common to all types of structure) must be examined.

3. To assess the effectiveness/longevity of various types of mud mix.

SURVEY OF FARMERS VIEWS OF THE BIMOBA MUD SILO, 1999

Since 1990 several projects have aimed at introducing mud silos into the Northern Region. Sasakawa Global 2000 and then the ADRA (Adventist Development and Relief Agency) collaborated with the MoFA in these projects. The main design introduced is the **Bimoba Mud Silo.**

The primary objective of the second survey was to reinforce certain findings from the survey performed in 1996. The specific objectives of this survey were to:

- determine farmers' views and impressions about the Bimoba Mud Silo

- determine the farmers willingness (and preparedness) to adopt the Bimoba Mud Silo in view of their ability to, firstly pay for its construction, and secondly to maintain it (especially for women and youth).

- assess the farmers' preference of the Bimoba mud silo as against their own traditional parallels, and the socio-cultural acceptability and gender balance/bias of the ownership, access and control of the storage structures with special reference to the Bimoba mud silo, and how these affect/would affect its adoption.

Forty one villages were visited within the Northern Region (Annex 2, Table A2.1). Communities where the survey was conducted fell into two categories: those into which the Bimoba mud silo was introduced by MoFA in collaboration with ADRA (a

[1] It was noted during the fieldwork that whilst transfer of ideas or good/bad points from one traditional design to another is almost non-existent, resulting in a stagnation of development, farmers can be receptive to new ideas brought in from the outside, as demonstrated by the general enthusiasm that has been shown towards the Bimoba silo around Tamale.

local NGO), and those where the mud silo was considered to be indigenous and to have been used for several decades.

Results

Annex 2 contains tables showing the details of the results obtained.

Gap between reality and expectation The findings indicate that there is little gap between reality and expectation of the effectiveness of mud silos. This gap was analysed by comparing and correlating responses from users and non-users of mud silos. The degree to which to which this gap varied was determined by plotting average values of variables for each category of farmers (i.e. users and non-users of mud silos).

The level of interest of non-users of mud silos was found to be influenced directly by the expectations of the effectiveness of mud silos in protecting their stored produce, and actual performance of mud silos reported by their colleagues using mud silos. For all communities surveyed, the evidence of interest of non-users of mud silos was quite high, and this confirms the premise that if the gap between reality and expectation is small, then farmers will be enthusiastic and willing to pay for mud silos.

Issues that are important to farmers:

- timing of construction: farmers complained that mud silo builders are sent to them late in the dry season. They said constructing mud silos soon after harvest would enable them to store effectively, and the timing of construction would not coincide with early rains, which is a source of worry.

- mass training of farmers: farmers said it would be very helpful to train many more builders (about 20 builders per village) so that the constraints of skilled labour will be reduced, and construction can be done early enough to avoid coincidence with early rains.

- knowledge of how to maintain mud silos: farmers said they are not satisfied with their level of knowledge of how to protect and maintain mud silos. They said farmers should, therefore, be trained in the protection and maintenance of their mud silos.

- flexible packages: From the survey, only one farmer was encountered owning a mud silo and was not a beneficiary of the MoFA/ADRA project. At present, only farmers in villages where MoFA and ADRA work have access to mud silo builders. Farmers said the technology should be extended to farmers in other villages outside the coverage of the MoFA/ADRA package.

Implications of findings to present conditions A number of changes needs to be made to the policies and planning of extension packages promoting the adoption and use of mud silos in order to facilitate the process.

- Packages should be extended and expanded to cover many more communities in order to achieve a ‘critical mass’ and therefore have an impact on the post harvest sub-sector at the regional or sub-regional level.

- Packages, when implemented in any community, should not be targeted to just farmers participating in MoFA/ADRA projects. There may be marginalised groups of people and/or other farmers' groups who, though not participating in those projects, have members who would be interested in mud silos.

- Packages should make provision for mud silo builders to spend more time in villages. During the survey, a number of ill-constructed mud silos were encountered and the owners explained that the builder was given only one week to construct more than eight mud silos, just when the rains were about to return.

- Packages should also include the training of local beneficiaries (farmers in their own settings) in the construction and maintenance of mud silos so as to remove the constraint on skilled labour as already mentioned above.

- If packages are to be extended or expanded, the involvement of local NGOs should be encouraged as this will reduce the burden on MoFA which is already constrained in terms of man-power.

- Above all, packages should be flexible enough to allow for various and different modes of repayment of credit and other inputs, if any.

Additional Research Areas The survey revealed that there is insufficient information and knowledge about farmers' storage behaviour. Much of previous work has been targeted at technical issues relating to post harvest handling and storage of agricultural produce, while little or nothing has been done to identify characteristics of farmers that influence their storage behaviour. Further research into these areas would remove constraints posed by the lack of knowledge of farmers' behaviour.

Secondly, further research is needed for a more detailed investigation into the availability of the different types of construction materials used for the construction of mud silos, and the technical effectiveness of these materials. Although suggested by some farmers, none have tested the suitability of the various materials mentioned as substitutes for the construction of mud silos. Such knowledge can then be used to avoid expensive mistakes in the future when the use of mud silos is extended into other areas within northern Ghana.

The issue or concept of 'good and poor storage hands' should not be discarded as a mere myth. Further investigations are needed to identify characteristics that influence the effectiveness of the use of 'good storage hands', and conditions under which the 'gift' operates. This will afford a better understanding of the concept and its potential exploitation for the betterment of the living standards of rural peoples.

Chapter 3

PHYSICAL COMPARISON OF STORES

STORES EXAMINED DURING THE TRIALS

The trials concentrated on comparing the Bimoba design of mud silo (as being extended by the MoFA) with the widely used Kambong design of timber structure.

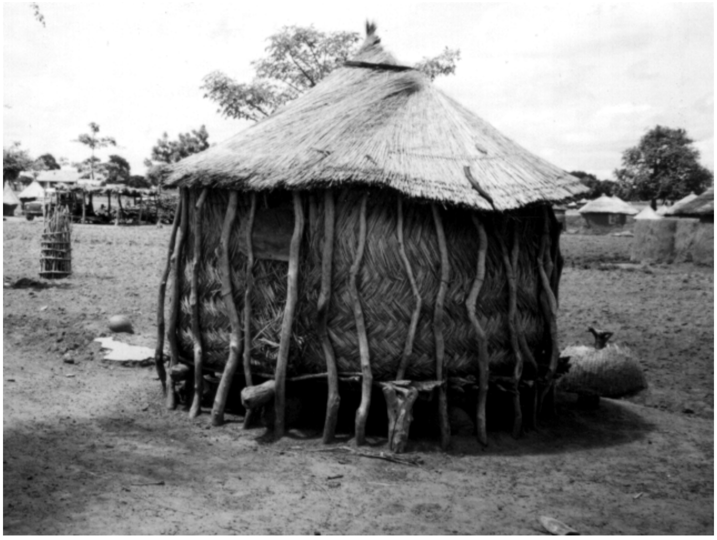

Plate 1 Typical Kambong store

Plate 2 Typical Bimoba mud silo

Sixteen mud silos of the Bimoba design, along with three Kambongs and a number of fired-clay water pots, had been constructed by NRI (as part of an earlier project, R6311, Fumigable Small-Scale Storage Structures) at the Savannah Agricultural Research Institute (SARI) at Nyankpala, near Tamale, in the Northern Region of Ghana. These silos were used by this project.

The silos, each of approximately 1.1 m high and 0.9 m in diameter, were constructed from a mud and grass mixture - the mud was sourced from local termite hills (as practised locally) and the grass had been cut into 50 mm lengths. Twelve of the 16 silos had a solution from a local plant known as the Beini creeper (obtained by crushing the woody stems and soaking for 24 hours in water) added to the mix – this was believed to improve the strength of the final silos. Each silo had a mud/grass lid which was mudded into position once the store had been filled and, where appropriate, instrumented. Four of the completed silos had then been rendered, on the inside and outside, with a soil/bitumen mix, and four with a cement render.

Figure 1 shows the layout of the experimental site, and Table 4 shows the various treatments applied to the different structures.

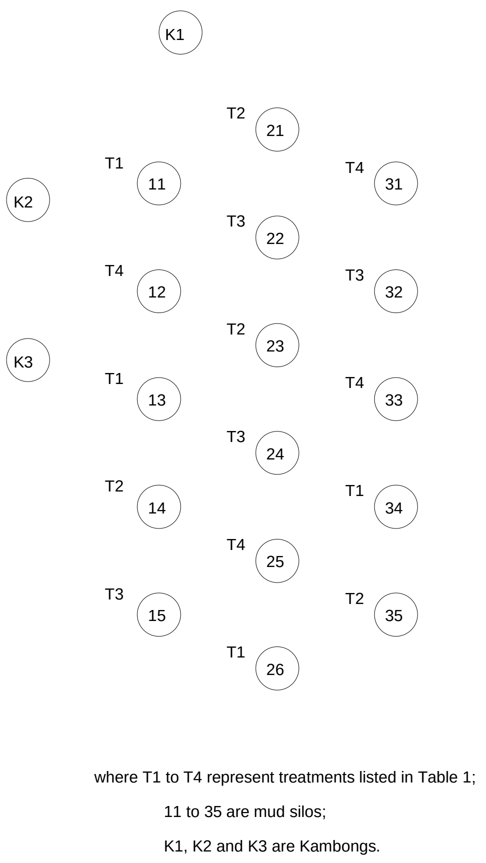

Figure 1 Layout of the experimental site

Table 4 Treatments applied to the various stores

Treatment	Material	Plastered	Silo No. (Figure 1)
T1	Mud and grass	none	11, 13, 26, 34
T2	Mud, grass and Beini creeper extract	none	14, 21, 23, 35
T3	Mud, grass and Beini creeper extract	soil/bitumen mix	15, 22, 24, 32
T4	Mud, grass and Beini creeper extract	cement	12, 25, 31, 33

During a preliminary trial from February to November 1996, three mud silos were instrumented, filled with grain, and monitored. These trials were reported by Brice and Ayuba in NRI Report No. R2356(S). Their results were used to develop further more detailed trials in which the physical characteristics and microbiological aspects of the stores were studied during the following storage season (December 1996 to September 1997).

Figure 2 shows monthly average temperatures recorded during the preliminary trial using three mud silos. Few significant temperature gradients occurred within the silos, but moisture contents increased significantly at the top compared to the centre of the silos. Although moisture contents had increased from approximately 10 % to between 14 % and 15 % by the end of the trials (thereby reaching the levels where the grain may be at risk from mould growth), moisture contents of nearer 11 to 12 % would be more likely in the typical storage periods up to August.

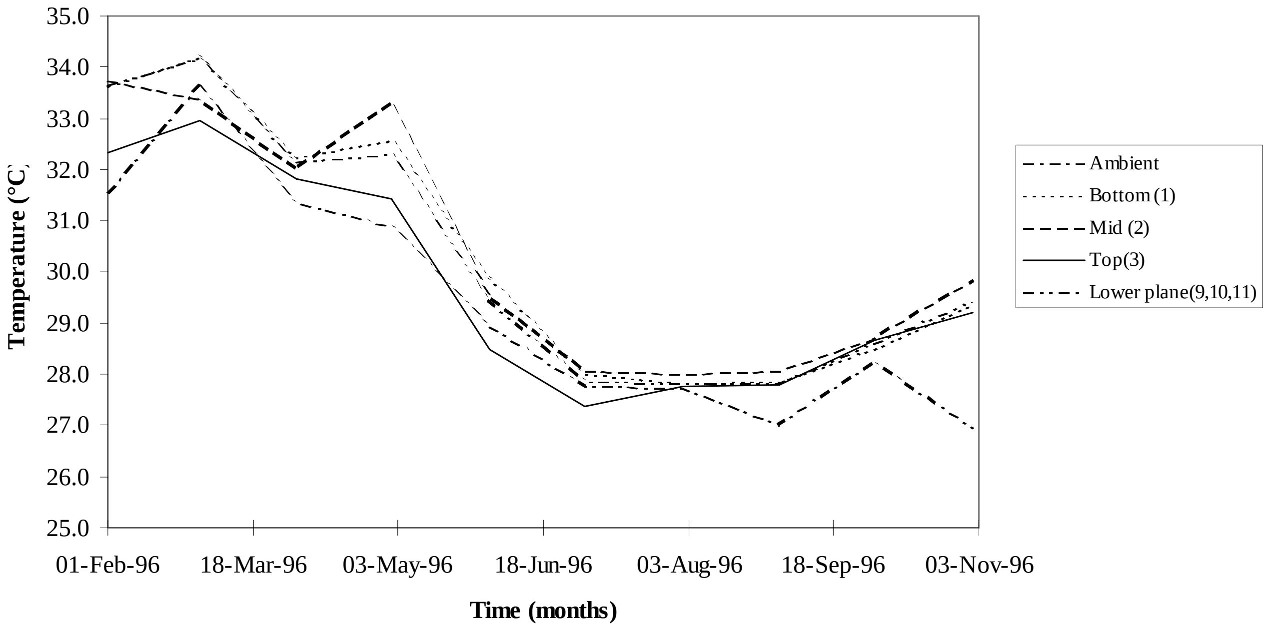

Figure 2 Average monthly temperatures in three mud silos during preliminary trials

Six of the mud silos (numbers 12, 13, 14, 22, 23 and 32, Figure 1) were selected for comparison to kambongs in the second trial. Their selection was primarily based on the results from earlier fumigation trials which showed that silos rendered and painted with an oil-based paint were more gas-tight than un-rendered silos, and therefore most likely to be able to contain elevated levels of CO_2. The following stores were used:

1. rendered mud silos (numbers 12, 22, 32, Figure 1);
2. unrendered mud silos (13, 14, 23);
3. kambongs (K1, K2, K3).

Approximately 3 tonnes of maize was purchased, mixed thoroughly and then used to fill the nine stores. During store filling, the stores were instrumented as shown in Figure 3. The sensors mid-way between the base and middle plane were placed against the side subject to the prevailing winds and rain.

Samples were taken during store filling and combined to form an initial composite sample – this sample was then used to provide information on the initial condition of the grain. The silos were sealed with a mud lid, and thatched roofs were placed on all stores when full.

Further samples were taken throughout each store during unloading and analysed, as with the initial composite sample, for microbiological and quality parameters.

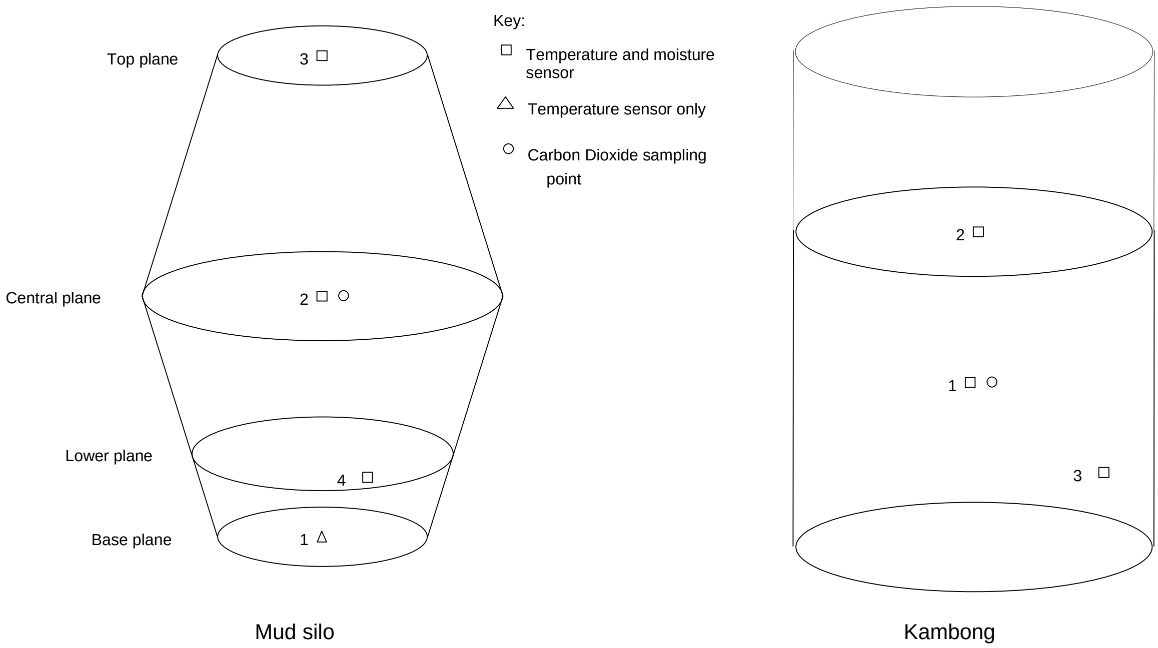

Figure 3 Schematic view of the sensor locations in the mud silos and Kambongs

In March 1997, 200 mm diameter access pipes were introduced through the lids of the stores to allow insect samples to be taken using a 1.2 m long sampling spear. When not in use, the upper-end of the tube was sealed with mud. Samples were taken on

20 March, 16 April, and 29 July. A fourth sample was examined at the end of storage.

TEMPERATURE

Figures 4, 5 and 6 show the mean monthly temperatures for the top, centre, base and wall positions for the three treatments (there was no base position for the kambong) and the ambient temperature.

Climatic variations in temperatures were reflected inside the mud silos but the patterns of temperature change appeared to vary over time. Up until the end of April the temperatures in all the mud silos tended to follow the changes in ambient temperature, rising then falling, but were hotter than ambient. As the ambient temperature continued to fall the silo temperatures also fell but at a slower rate, and in the base and centre of the unrendered silos they rose. Temperatures in the individual silos also diverged more as the trial continued, resulting in a spread of grain temperatures by the end of the trial of between 32ºC and almost 40ºC compared to ambient temperatures of approximately 29ºC. All temperatures started to rise again at the end of the trial, following the rise in ambient temperatures.

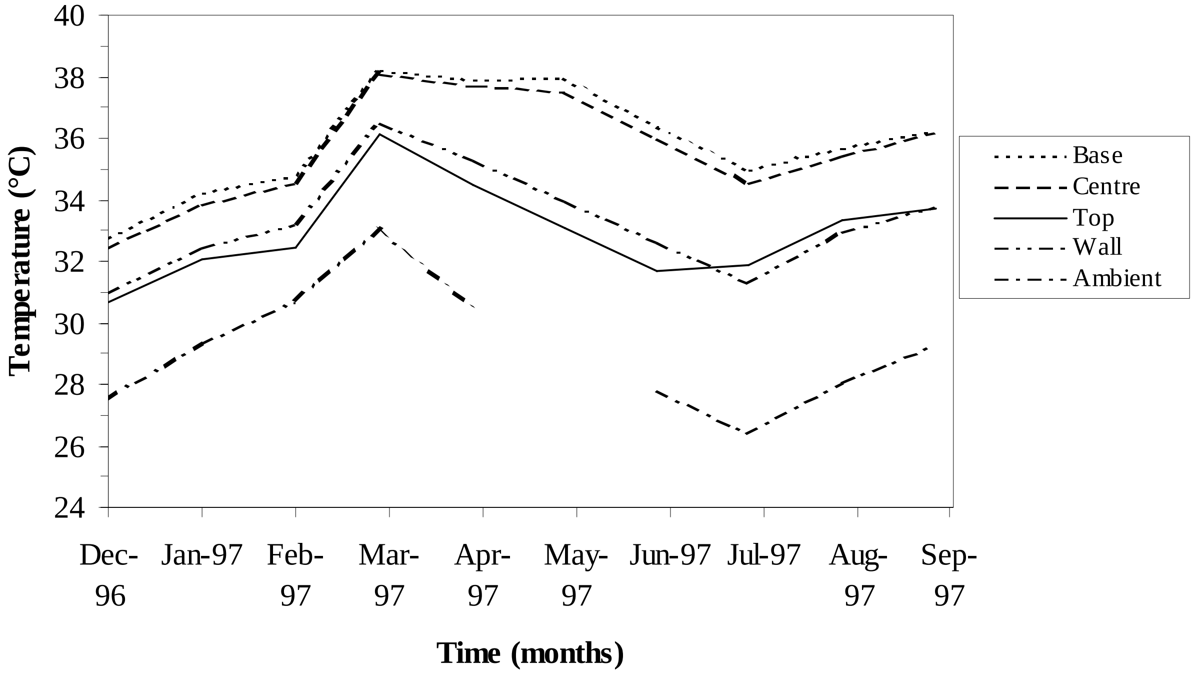

Figure 4 Mean monthly temperatures for positions in the rendered mud silos

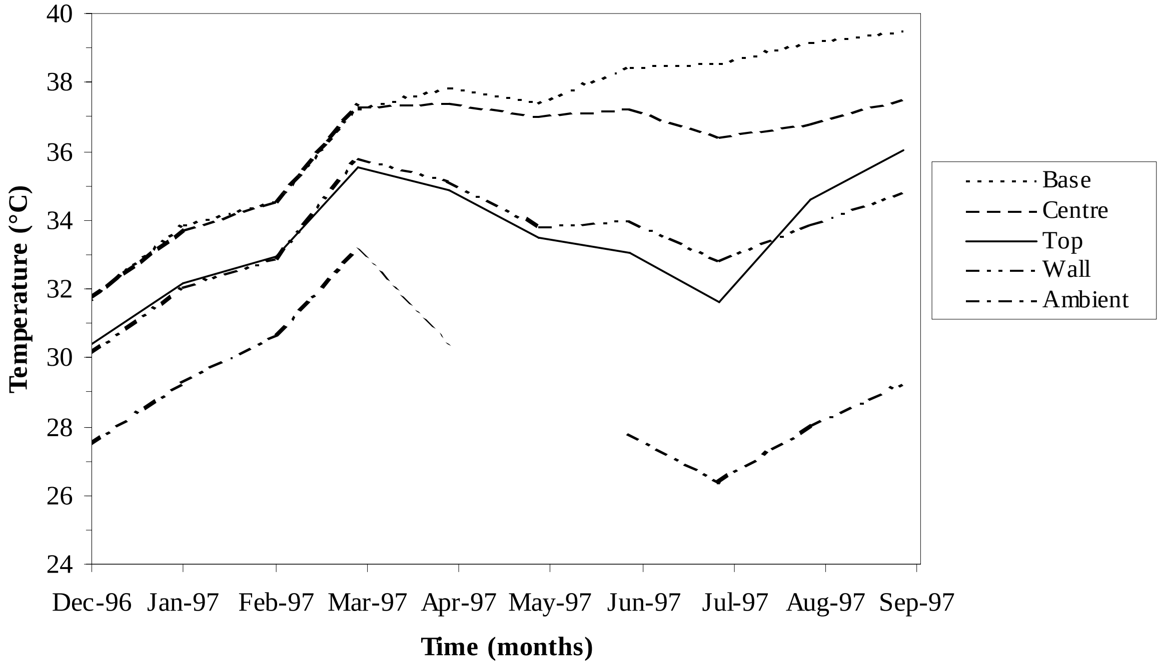

Figure 5 Mean monthly temperatures for positions in the unrendered mud silos

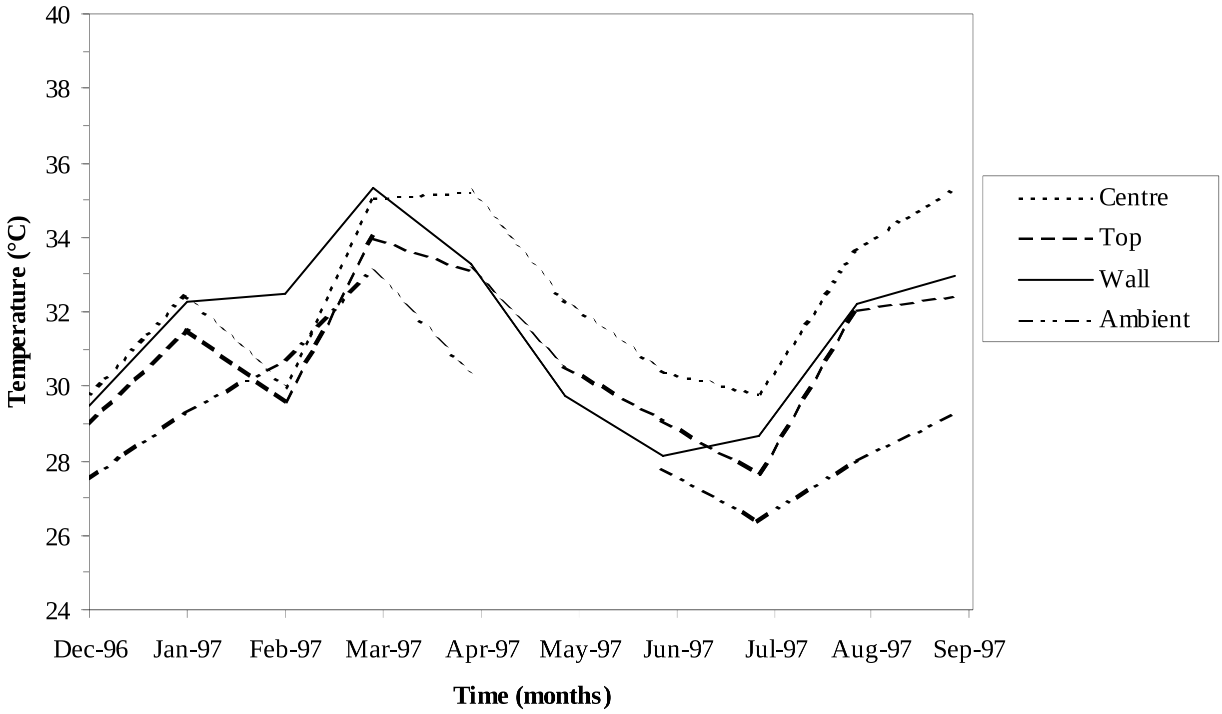

Figure 6 Mean monthly temperatures for positions in the kambong stores

Temperatures within the kambongs followed the ambient temperatures far more closely. Up to the end of April the temperatures in the Kambongs remained at a fairly constant 2ºC to 2.5ºC lower than those in the mud silos. From May onwards, i.e. while the mud silo temperatures fell more slowly than ambient, the temperatures in the kambongs continued to fall with the ambient conditions, eventually reaching approximately 27ºC by the end of June - between 5ºC and 9ºC cooler than the mud silos.

ANOVA was applied to the mean monthly average temperatures to investigate the effect of treatment and position. Tables 5 and 6 show the means for treatments and positions respectively. There was very strong evidence of differences due to both the treatment ($F_{(2,26)} = 39.9$, $P < 0.001$) and position in the store ($F_{(2,26)} = 28.9$, $P < 0.001$). Further analysis showed no significant differences between the two mud silo treatments ($t_{26} = 1.9$, $P = 0.069$) but highly significant differences between the average of the two mud silo treatments and the kambongs ($t_{26} = 11.0$, $P = 2 \times 10^{-9}$). There were also highly significant differences between the temperatures at the top ($t_{26} = 6.58$, $P = 6.0 \times 10^{-7}$), wall ($t_{26} = 5.6$, $P = 7.0 \times 10^{-6}$) and base ($t_{26} = 4.2$, $P = 0.0003$) of the stores and at the centres.

Table 5 Mean temperatures for each treatment (store type) for all positions. S.e.d. between treatments 1 and 2 = 0.3°C. S.e.d. between treatment 3 and the average of treatments 1 and 2 = 0.28°C.

Treatment	Mean temperature (°C)	n
1 (rendered mud silos)	34.4	12
2 (unrendered mud silos)	35.0	11
3 (Kambongs)	31.6	9

Table 6 Mean temperatures for each position for all treatments. S.e.d. between centre and wall, and centre and top = 0.34°C. S.e.d. between centre and base = 0.4°C.

Position	Mean temperature (°C)	n
Base	36.4	5
Centre	34.7	9
Wall	32.8	9
Top	32.4	9

The main conclusion from these data is therefore that the kambongs were cooler than the mud silos, being close to ambient conditions throughout storage. This is presumably due to their more open, woven construction allowing air circulation and therefore removal of solar heat from within the stores, and the insulating properties of the walls in the mud silos. Although the two mud silo treatments (rendered and unrendered) showed slightly different patterns of temperature change, their overall mean temperatures showed no significant differences.

MOISTURE CONTENT

Figures 7, 8 and 9 show the moisture content changes averaged over the top, wall and centre positions for the three treatments. These have been corrected to the actual moisture content, determined by laboratory analysis, at the start of the trial, which were close to the safe moisture content limit of 14%.

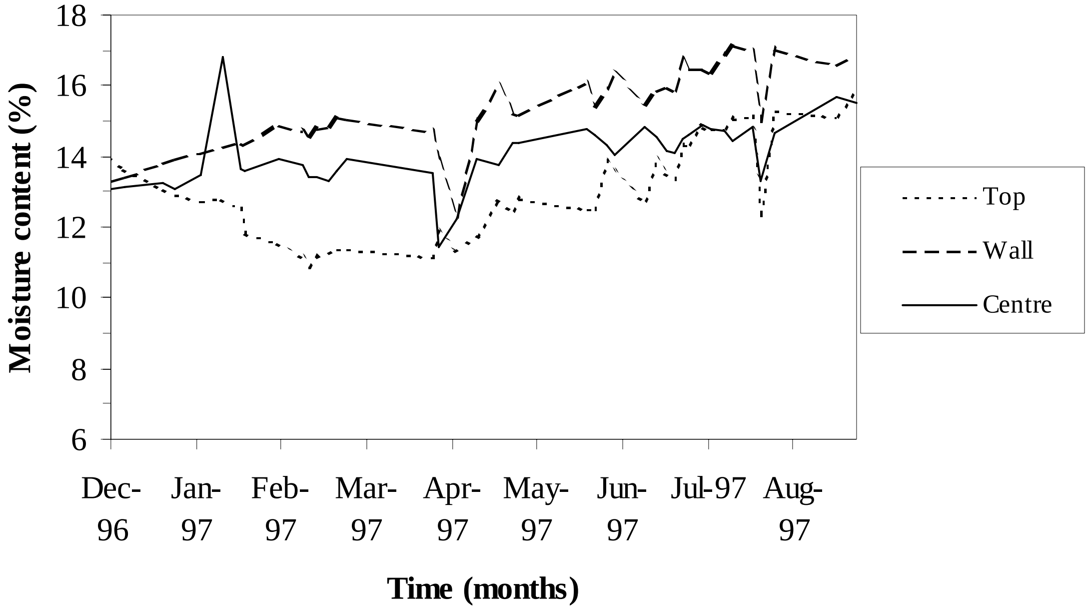

Figure 7 Average moisture contents in the rendered mud silos

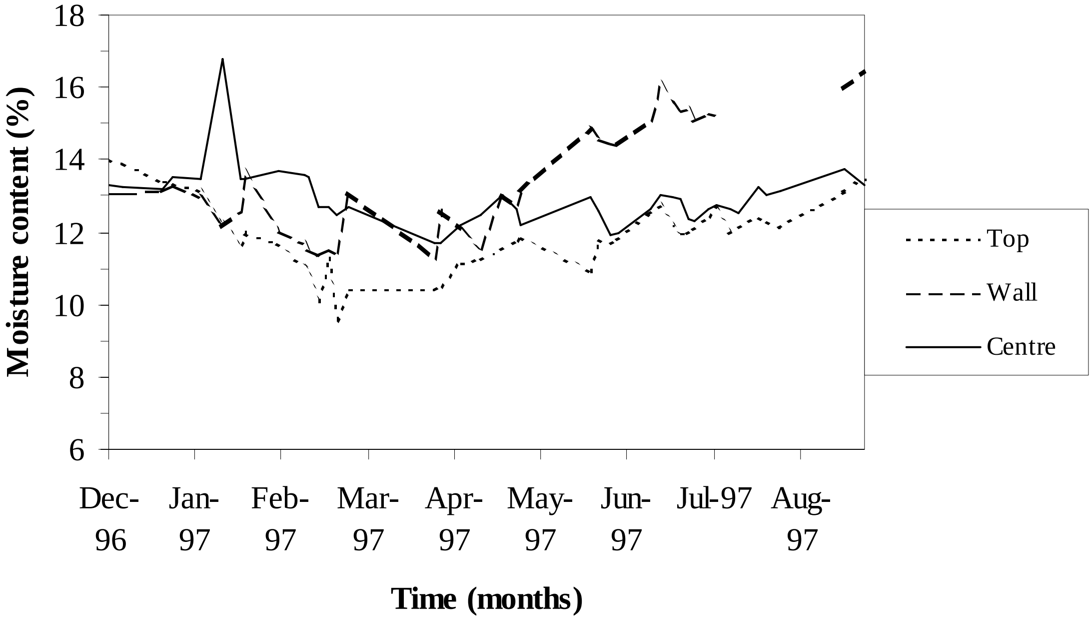

Figure 8 Average moisture contents in the unrendered mud silos

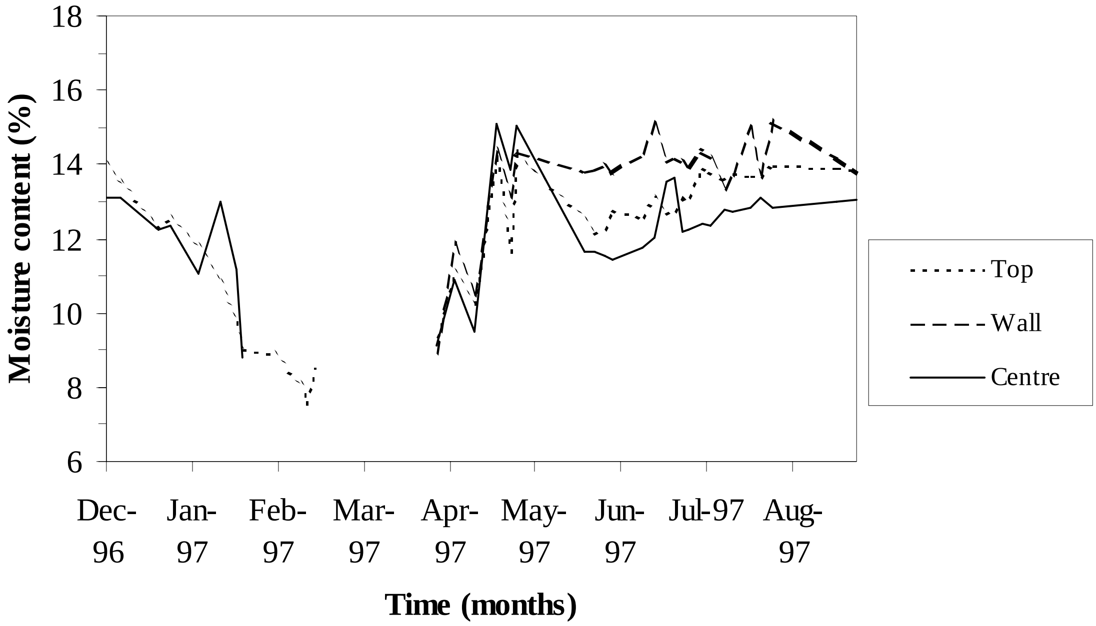

Figure 9 Average moisture contents in the Kambong stores

Initially the moisture contents fell, though not near the wall or at the centre of the rendered silos. The fall was sharpest in the Kambongs, where it reduced the moisture content to as low as 8% in comparison to 12% or above in the mud silos. The moisture content rose in all stores after the end of April. This corresponded to the beginning of the rainy season, which continued until early August. The mud silos showed a slow rise during this period, the walls being the most greatly affected. The Kambongs by contrast showed a very steep rise in moisture content over a short period from April to May, followed by steady values. This would suggest that the grain in the Kambongs were more open to the wetting effects of the atmosphere during the rainy season, causing rapid rises in moisture content, whereas the mud silos were better sealed, causing slower moisture content rises.

The high moisture contents in the wall positions suggest that, despite the large roof overhangs, wind-blown rain wetted the lower portion of the silo walls and soaked through to the grain inside. The tops of the stores also tended to have high moisture contents, and the lowest moisture contents tended to be at the centres of the stores. This suggests that ambient conditions during the trial were such that they led to an overall rise in the moisture content of the stored grain, and that this slow process occurred at the tops and sides of the stores where they were exposed to the atmosphere.

In general the moisture contents reached by the end of the trial were at or above the safe level of approximately 14%, with some individual positions reaching 20%, leading to the conclusion that mould growth may have occurred.

The moisture contents determined from the samples at the end of the trial were analysed using ANOVA to determine whether there were any effects due to the treatment or position within the stores at the end of the trials. Table 7 shows the means for the three treatments. The only significant effect was that due to the treatment ($F_{(2,26)}$ = 3.96, P = 0.038). There were no significant differences between the two mud silo treatments (t_{18} = 1.57, P = 0.134), but a significantly lower moisture content in the Kambongs than in the average of the two mud silo treatments (t_{18} = 2.42, P = 0.026). Table 8 shows the mean final moisture contents by position. There was no significant difference between the wall and centre means.

Table 7 Table of means for final moisture content (m.c.) averaged across all positions for each treatment. S.e.d. between the two mud silos = 0.7%, s.e.d. between the average of the mud silos and the Kambongs = 0.6%.

Treatment	Mean final m.c. (%)
1 (rendered mud silos)	16.0
2 (unrendered mud silos)	14.9
3 (Kambongs)	14.0

Table 8 Table of means for the final moisture content for each store position averaged across all treatments. S.e.d. between each position and the centre = 0.7%.

Position	Mean final m.c. (%)
Walls	15.5
Top	15.2
Centre	14.2

The overall conclusion from the moisture content data confirmed the findings from the temperature monitoring, namely, that the more open wall construction of kambongs meant that grain conditions were closely affected by the ambient conditions. Although grain moisture contents generally followed a fall-then-rise pattern, this was more pronounced in the Kambongs, but that the Kambongs finished with a lower average moisture content than the mud silos. Although the two mud silos treatments showed slightly differing moisture content trends, the final moisture contents reached were not significantly different. The maize was initial at a relatively high moisture content and had reached unsafe levels at many positions, particularly tops and walls, by the end of the trial. To avoid this, and assuming a similar overall rise in moisture content to that which occurred in this trial, maize should be dried to around 11% moisture content for storage in the mud silos and around 12% for the Kambongs.

FUNGAL INFECTION

Grain samples were analysed to identify fungi by surface sterilising and plating fifty grains each onto Dichloran Rose Bengal Chloramphenicol agar (DRBC) and Dichloran 18% Glycerol agar (DG18) at five grains per plate. The former medium allowed the identification of general fungi, whilst the latter identified more xerophilic fungi. The plates were incubated at 27°C for five days. For the initial samples an additional 50 grains were plated onto DRBC without prior surface sterilisation to isolate the surface flora. Since no atypical results were observed, this was not done when examining the grains at the end of the trial.

The percentage of seeds infected with fungi was determined, and individual species identified to assess the extent of damage and the potential mycotoxin producers (Tables 9 and 10). Due to the number of samples examined at the end of storage the data represented in Table 9 is a summary of the most important findings: some 30 species of mould were identified in total.

Table 9 Fungal infection of maize grains at the beginning of the storage trial (as a composite of results from DRBC and DG18)

	Percentage of maize grains infected with individual fungi					
	Surface Sterilised Grains			Non-surface Sterilised Grains		
	Sample 1	Sample 2	Mean	Sample 1	Sample 2	Mean
Aspergillus flavus	84	98	91	100	100	100
Aspergillus niger	2	2	2	70	100	85
Penicillium spp.	54	0	27	20	30	25
Fusarium moniliforme	86	86	86	20	10	15
Rhizopus stolonifer	4	0	2	100	100	100
Nigrospora oryzae	8	4	6	4	0	2

all plates used in this examination exhibited some infection

Table 10 Average fungal infection of maize grains at the end of the storage trial (as a composite of results from DRBC and DG18, most important results only)

	Percentage of maize grains infected with individual fungi		
	Rendered silos	Unrendered silos	Kambongs
Aspergillus flavus	24.4	26.9	55.6
Eurotium spp.	28.8	29.7	27.3
Rhizopus spp.	6	9.5	11.7

The results from the beginning of storage indicate that the samples were heavily contaminated on their surfaces with a range of fungi, and that some of these had penetrated a large percentage of the grains. The extremely high levels of *Aspergillus flavus* recorded indicated that the grains may have become contaminated with aflatoxins. Levels of infection with *Fusarium moniliforme* were also very high, and it is possible that the grains may have been contaminated with fumonisins and other *Fusarium* toxins.

Heavy fungal rotting was observed during unloading throughout silo 12 and on the top half of the grain in silo 14, and on the wall towards the base of silo 32 near where termites had entered the silo. No visible moulding was found in the silos 13, 22 and 23. It was also noted that the two mud silos which had visible mould growth on the top surface were those with no gap between the top of the grain and the lid.

Considerable changes had occurred in the mycoflora by the end of the trials. The percentage infection of grains with *Aspergillus flavus* were much more variable, indicating that changes in storage conditions had occurred. There were also far more fungal species identified after storage (30 species although only the three most important ones are reported in Table 10), which may reflect changes in storage conditions or contamination from the silos walls or from insects, particularly termites. Percentage infection with *Fusarium moniliforme* had declined markedly, while there was a rise in infection with *Eurotium* spp. and *Aspergillus penicilloides*. These species grow after harvest when the equilibrium relative humidity (e.r.h.) is between 70% and 90%, approximately 13.5 – 19% moisture content. These changes are typical of grain stored in conditions that are too wet. Species of *Chaetomium* are associated with sources of cellulose and grow under high e.r.h.(>90%). It is possible that they were introduced by termites which would be associated with sources of cellulose.

The results at the end of storage were analysed using ANOVA to test for effects of treatment and position. The percentage counts for *Aspergillus flavus* were used, with an angular transformation applied. The results of the analysis showed that the assumptions underlying ANOVA were not completely satisfied (the data was not normally distributed), therefore the analysis must be viewed with some caution. It showed that the only significant effect was due to treatment, and that this was highly significant ($F_{(2, 30)} = 11.78$, $P < 0.001$). Contrasts as before showed a highly significant difference between the mud silos and the Kambong ($t_{30} = 5.33$, $P = 0.00001$). Table 11 shows the table of means for the three treatments.

Table 11 Table of means (untransformed and with an angular transformation) for percentage of grains infected with *Aspergillus flavus* at the end of the trial. S.e.d. between the transformed mud silo means = 0.11, s.e.d. between the average of the transformed mud silo and Kambong means = 0.1.

Treatment	n	Mean (%)	Transformed mean
1 (rendered mud silos)	16	26.4	0.288
2 (unrendered mud silos)	18	34.7	0.375
3 (Kambong)	14	69.4	0.859

MYCOTOXIN ANALYSIS

The levels of mycotoxins in the maize samples taken at the beginning and end of the trial are summarised in Tables 12 and 13.

Table 12 Mycotoxin levels at the beginning of the trial

	Aflatoxin (µg/kg)				
	B1	B2	G1	G2	Total
All stores	190	10.3	-	-	200.3

Table 13 Mean mycotoxin levels in each store type at the end of the trial

Store treatment	Mean aflatoxin level (µg/kg)				
	B1	B2	G1	G2	Total
1 (rendered mud silos)	42.0	6.5	1.2	0.4	50.1
2 (unrendered mud silos	75.8	9.3	6.1	1.7	92.9
3 (kambongs)	143.9	17.7	4.8	0.7	167.1

The high levels of B type aflatoxins found in the initial maize sample reflect the high levels of *Aspergillus flavus* discovered during the fungal investigations - *Aspergillus flavus* produce only B toxins. The UK regulatory maximum level of total aflatoxin content is 10µg/kg for human consumption. The high level of mycotoxins before and after storage, up to 200 µg/kg, are therefore of serious concern.

Table 13 shows that the Kambong stores appeared to have the highest levels of aflatoxin at the end of storage – ANOVA analysis was attempted but the underlying assumptions were not met (not normally distributed). This result correlates with the significantly higher levels of *Aspergillus flavus* in the Kambong stores.

The conditions for *A. flavus* growth are given as optimal at 28°C, with a maximum of 31-37°C, and a minimum of 80 – 85 % relative humidity. Aflatoxin is produced above 82% relative humidity and optimally at 95 – 99% relative humidity. Temperatures were, therefore, on the high side in the stores, though were closet to ideal in the Kambong stores. The high moisture contents needed for the relative humidity to reach above 80% (16% or higher), were reached in some positions mainly near the walls of the mud silos. Conditions were therefore suitable for some moulds to grow but not ideal for aflatoxin production. The apparent reduction in aflatoxin during storage may have been due to sampling errors, aflatoxin production being highly variable, or may have been due to degradation by *A. flavus* and/or *Rhyzopus stolonifer* during storage.

Conclusions on the relative performance of the stores are difficult to draw because the maize at the start of the trials was so heavily infected with fungi, contaminated with mycotoxins and at a relatively high moisture content. It could be concluded that the Kambong stores resulted in the highest levels of moulds and mycotoxins, but this may simply be because these contaminants were reduced less in these stores from their initial high levels than in the other stores. Further trials are necessary to clarify the relative performance of the stores in this respect.

INSECT INFESTATIONS, CO_2 LEVELS AND OTHER DAMAGE

Grain samples were extracted in March, May, July and at the end of the trial in September 1997 using the sampling spear and were used to assess insect populations. Each sample was incubated for 30 days in a glass jar after weighing and removal of insects. Table 14 lists the numbers and species of insects found.

Analysis using ANOVA showed conflicting results. In the results from September there were significantly more *Sitophilus* spp. in the Kambongs than in the mud silos ($t_6 = 18.22$, $P = 1.78 \times 10^{-6}$), which Table 14 shows had developed since the samples taken in July, while there were significantly more *Rhyzopertha* spp. in the unrendered silos ($t_6 = 5.74$, $P = 1.22 \times 10^{-3}$), and no significant differences for the other species. There is the possibility that the Kambongs were more open to infestation than the mud silos, though this only appears to have allowed a *Sitophilus* spp. infestation to develop.

Termite damage to both the storage structure and to the grain itself was found in some of the silos at the end of the trial. There appears to be no pattern to the damage, though none of the Kambongs were affected.

Grain samples were analysed for insect damage, moulds and brokens before and after storage (7 December 1996, and 26 September 1997 respectively). The results are shown in Table 15.

There were no significant differences due to the treatments. Insect damage was clearly very high at the end of storage in all treatments which agrees with the insect analysis above which showed high levels of insects in all store types. It may therefore be concluded that all store types are equally prone to insect infestation and subsequent damage, though there may be differences between the insect spectrums of the different store types. Some form of insect control is therefore necessary.

Table 14 Insect populations present in the stores during the storage period

***Sitophilus* spp.**

Store	Numbers of Live Insects per kg of maize			
	March	May	July	September
12	0.72	7.70	0.00	4.12
13	0.00	1.10	0.00	9.65
14	0.66	7.81	0.00	6.81
22	0.54	0.00	0.00	3.72
23	0.00	0.00	0.00	21.29
32	0.51	0.00	0.00	11.72
K1	0.00	0.00	38.94	195.39
K2	0.00	0.53	0.00	246.70
K3	0.00	0.00	23.79	209.85

Tribolium castaneum

Store	Numbers of Live Insects per kg of maize			
	March	May	July	September
12	1.44	49.41	7.35	50.21
13	1.92	22.01	24.90	42.98
14	1.33	12.02	282.47	17.04
22	0.54	53.67	50.04	117.10
23	2.87	47.17	37.26	159.70
32	5.12	107.27	63.58	24.12
K1	12.59	17.98	28.89	100.20
K2	6.36	20.23	49.33	11.17
K3	0.00	4.70	13.35	17.34

Rhyzopertha dominica

Store	Numbers of Live Insects per kg of maize			
	March	May	July	September
12	0.72	0.72	6.68	0.82
13	0.96	0.96	11.79	57.02
14	1.33	1.33	25.11	43.44
22	0.00	0.00	6.26	2.79
23	4.60	4.60	9.17	59.32
32	2.05	2.05	9.26	17.92
K1	1.94	1.94	30.78	28.06
K2	7.27	7.27	6.96	0.00
K3	1.85	1.85	10.45	4.56

***Cryptolestes* spp.**

Store	Numbers of Live Insects per kg of maize			
	March	May	July	September
12	5.03	6.42	8.02	98.77
13	23.08	24.77	17.04	38.60
14	9.96	18.03	31.39	22.15
22	21.65	17.29	5.00	17.66
23	17.24	9.54	84.84	98.86
32	24.07	33.25	19.75	29.63
K1	9.69	7.70	6.28	168.34
K2	7.27	3.19	3.16	31.47
K3	0.00	4.18	1.16	29.20

Table 15 Quality of grain at the beginning and end of the trial

	Percentage of the sample (%)			
	Good	Insect damaged	Broken[1]	Mouldy
Beginning of the trial	90.99	0.91	5.06	3.04
End of the trial			'Destroyed'	
1 (rendered mud silos)	54.3	44.2	1.54	nr
2 (unrendered mud silos)	43.4	52.9	3.72	nr
3 (Kambongs)	62.5	35.6	1.94	nr

Carbon dioxide concentrations within each of the silos were recorded at regular intervals during storage using a Bedfont CO_2 meter. Average CO_2 concentrations for each treatment plotted against time are shown in Figure 10. The concentrations in the mud silos rose throughout storage and were all higher than those in the Kambongs, which remained at less than 1% CO_2 until the end of storage when they rose to approximately 2%. The two mud silo treatments showed very similar trends, suggesting that there was no difference between them. These results support the conclusion that the Kambongs are better ventilated than the mud silos, which appear from the accumulation of CO_2 to be relatively well sealed.

Without being able to measure oxygen levels during the trials, it is difficult to comment on how effective the increases of CO_2 are likely to be. Bailey 1955 (in FAO, 1973) indicates that oxygen levels play an important part in determining the levels of CO_2 required for mortality – at high O_2 levels (15 to 21%) the CO_2 must be as high as 36% to obtain sufficient mortality of adult weevils (*Sitophilus granarius*) although immature stages succumbed at lower concentrations (approx. 19% CO_2). Since the highest CO_2 concentration recorded was below 8% it is unlikely that such conditions would have any pronounced effect on insect numbers.

[1] The number of broken grains was counted at the beginning of the trial, the number of destroyed grains was determined at the end.

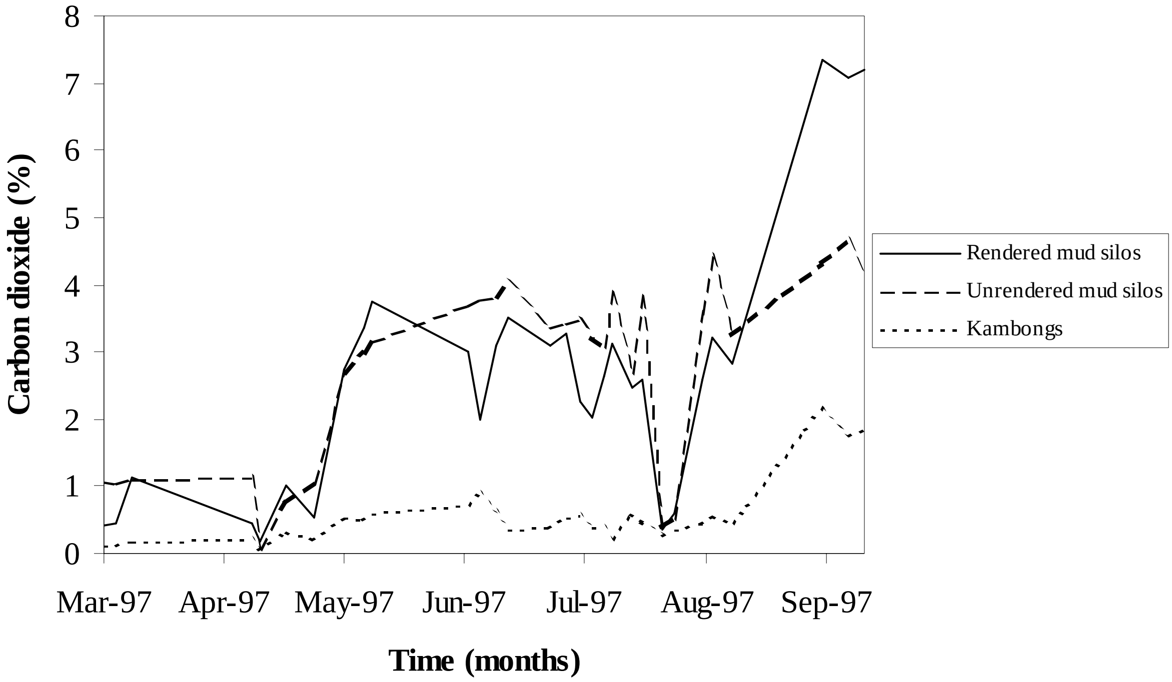

Figure 10 Carbon dioxide concentrations during storage

Although precautions were taken to minimise disturbance, Figure 10 shows that conditions were affected during May and July when insect samples were taken from the mud silos. Possible sources of the high carbon dioxide levels in the stores could have been the growth of moulds and insect infestations, both of which occurred in all of the stores. It may be concluded that higher concentrations of carbon dioxide occurred in the mud silos than in the Kambongs, and that rendering of the mud silos caused no differences to the levels.

Chapter 4

TERMITE PROOFING

A preliminary trial was undertaken to examine the susceptibility of mud materials with various treatments to termite attack in Upper East Region (UER), where termites are a particular problem, in December 1996. The data collected provided a useful indication of the types of termites present and, to some degree, the effectiveness of some proofing treatments.

TERMITE CONSULTANTS' REPORT

A consultant was employed in September 1997 to visit the trials and surrounding area to identify the types of termites present in the area, to advise on the preliminary trials and to make recommendations for future trials (Mitchell, M., 1997). His findings are summarised below:

- termite damage was extremely widespread in the areas visited (Northern and Upper East Regions), necessitating frequent replacement of buildings and even movement of the whole homestead;
- several different genera of termites were identified, the three main ones being *Macrotermese* spp., *Coptotermes* spp., and *Amitermes* spp.;
- of the various types of structure found in the two regions, the mud silo is probably the easiest to protect against termite attack;
- a number of physical and chemical treatments were suggested as possibly being suitable for protecting mud silos.

Mr Mitchell concluded that the numbers of various soil-nesting termites can be reduced or even eliminated by providing an effective barrier between the structure and the soil. Protection against termites which have the potential for nesting in the walls is more difficult – one way around this may be to make the walls thinner where possible, so reducing the bulk of material in which nests could be built. The maintenance of a smooth wall surface, and the regular inspection for cracks and holes would also be a sensible precaution.

ON STATION TRIALS

On-station trials were established at the SARI trial site in 1998 to test the hypotheses put forward by the consultant. Soil samples were treated with one of 12 treatments (6 physical barriers and 6 chemical treatments, Table 16, 6 replications of each treatment).

Table 16 Treatments applied to assess their effectiveness against termite attack

Code	Treatment
Physical Barriers	
1	Mud and Grass on a concrete block
2	Mud and Grass on a concrete block, separated by a galvanised sheet turned-down at the edges
3	Mud and Grass moulded over a concrete block
4	Mud and Grass in a plastic bucket (base of bucket intact) on a concrete block
5	Mud and Grass in a plastic bucket (base of bucket intact) on the ground
6	Mud and Grass in a plastic bucket (base of bucket removed) on the ground
Chemical Treatments	
7	Mud only
8	Mud and Grass
9	Mud and Grass mixed with Old Engine Oil
10	Mud and Grass mixed with Bitumen
11	Mud and Grass mixed with 'Vitso' extract
12	Mud and Grass mixed with Chloropyrifos

Pieces of wood were placed on top of each of the soil samples – these were examined at regular intervals during the trial to assess the levels of termite activity.

Levels on termite damage over a nine month period are plotted in Figure 11. The following treatments showed no sign of termite infestation:

- On a concrete block
- Concrete block + galvanised sheet
- In plastic bucket + over concrete block
- Plastic bucket
- + old engine oil
- + Chloropyrifos

Since plastic buckets are expensive, they are probably not appropriate for many of the poorer farmers in the northern regions of Ghana. Concrete blocks can be replaced by more commonly available stones to provide effective barriers against termite infestation.

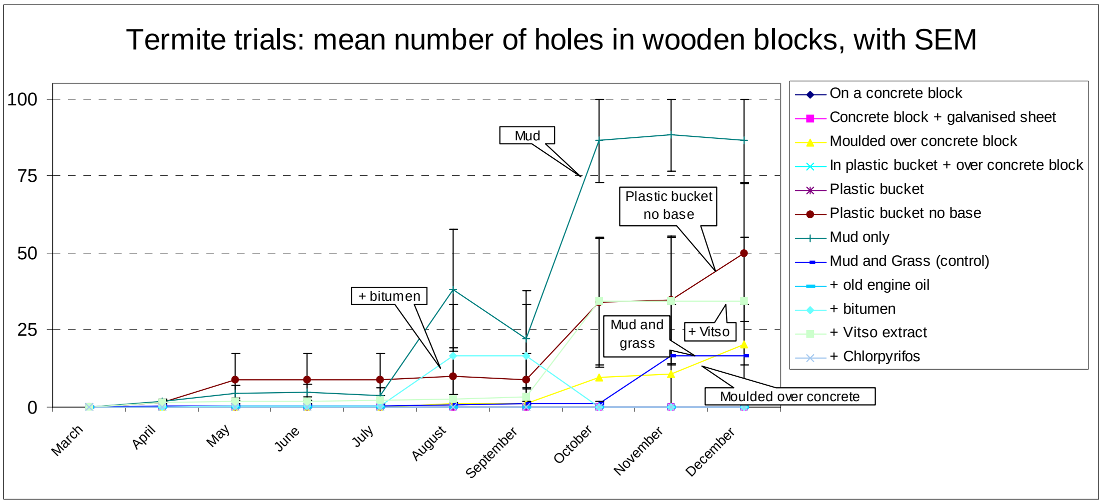

Figure 11 Rates of termite infestation of on-station termite trials

ON-FARM TRIALS

Following the recommendations from the on-station trials, and the identification of so-far untried treatments, the following treatments were selected for on-farm trials (the treatments being applied to the three legs of specially constructed small silos):

- Mud and grass moulded over the stone (control)
- Mud-only (added at the request of local farmers who believe that straw mixed in the mud attracts termites)
- Mud, grass, and old engine oil
- Mud and grass built on a stone and a galvanised sheet
- Mud, grass and neem seed extract
- Mud and grass built on a stone

Forty family-compounds were selected for the trials from three adjoining villages (Bongo central, Borigo I and Borigo II) in UER. Each treatment was applied to a small thatched mud silo containing approximately 50 kg of sorghum built on a farmer's premises. The five treatments tested were replicated either 6 or 8 times. As with the on-station trials, a piece of wood (placed on top of the grain inside each of the stores) was used to indicate termite activity. Regular inspection and sampling assessed the level of damage and termite attack, which is shown in Figure 12.

Very few of the trial silos were damaged by termites (Figure 12). This was most likely due to the farmers' diligence - despite requests from the MoFA/NRI team not to modify the designs of the silos or interfere with the trials, farmers insisted on controlling termites when they saw them and, in several cases, plastering them with dung or mud after the start of the trial (effectively adding another treatment over the desired treatments making analysis very difficult). With such little termite activity it is impossible to make any analysis and draw any firm conclusions.

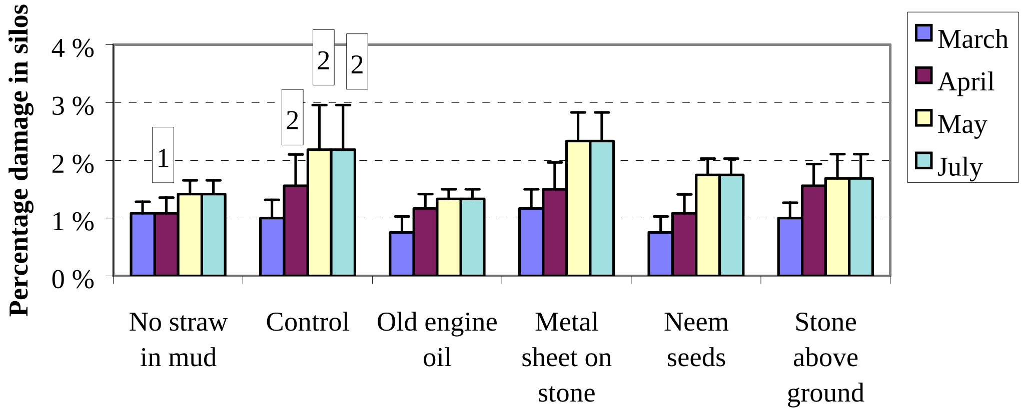

Figure 12 Damage to grain and silos during on-farm termite trials (numbers refer to the number of holes in one wooden block).

Chapter 5

DURABILITY OF MUD MIXES

Mud structures in the three northern regions of Ghana are constructed from a variety of materials. Mud is rarely used alone: other materials are usually added, e.g. grass is invariably used to improve the mechanical strength of the structure, and a number of plant-derived solutions are commonly used which supposedly improve either the strength or the wear resistance of the walls - the latter are either added to the soil-mix or are painted on to the finished walls. Some farmers also plaster the walls with cement or a bitumen/mud mix.

A trial was established to test the durability of mud mixes incorporating the more commonly used materials. Sections of walls were constructed in wooden frames approximately 0.86 m high by 0.86 m wide and 0.15 m deep using the six mixtures listed in Table 17. Three replicates of each were used. These wall sections were then stood upright in three lines (in random order), with the wall surfaces facing the prevailing wind and rain.

Table 17 Wall compositions used to assess the durability of different mud mixes

Type	Mud mixture
A	Mud only
B	Mud, Grass mix
C	Mud, Grass, Beini mix[1]
D	Mud, Grass, Beini mix with Dawa-dawa sprayed on surface[2]
E	Mud, Grass, Beini mix + Dawa-dawa + Cement rendering
F	Mud, Grass, Beini mix + Dawa-dawa + Soil/Bitumen rendering

The surface condition of each wall section was monitored over time. This was achieved by taking measurements of the depth of erosion at 16 points on the surface of each wall using a grid of strings held across the surface of each wall in turn. The roughness of each wall was then defined as the difference between the minimum and the maximum readings.

The walls were constructed in December 1996 and readings commenced in May at the start of the rainy season. The mean cumulative changes in roughness were calculated for each treatment and are shown in Figure 13.

[1] Solution from crushed Beini creeper – when soaked in water for 24 hours this produces a slimy solution which is mixed with the mud and is claimed to improve its binding properties.

[2] Painting the finished wall with Dawa-dawa solution - pods from the Dawa-dawa tree are soaked for 24 hours. The solution appears dark in colour but its viscosity does not appear to be affected. It is claimed to improve the walls’ resistance to rain erosion.

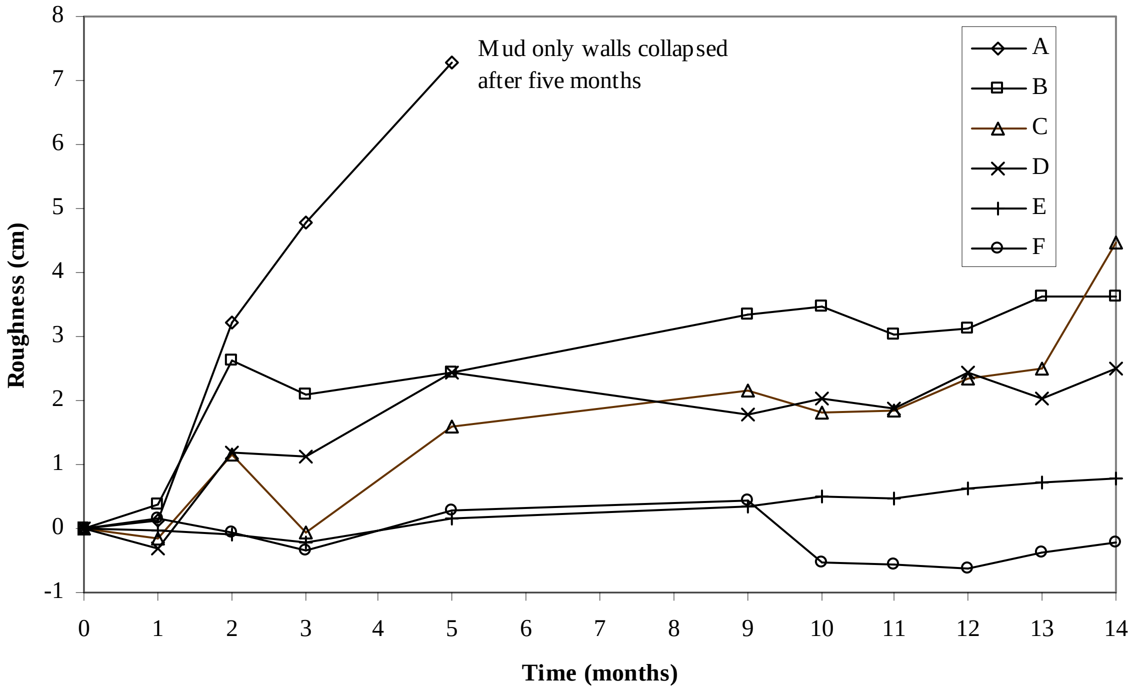

Figure 14 Cumulative changes in mean roughness of the wall surfaces for six mud mixes

The mud-only walls (treatment A) deteriorated rapidly and eventually collapsed. As all other treatments were still standing at the end of the trial it may be concluded that it is essential to add grass to the mud mixture.

Treatments B, C, and D were all eroded by the end of the trial, producing a rough surface with much of the grass exposed. Some fine cracking was evident but followed no particular direction. It may be concluded that protection from rain must be provided for walls of this nature, e.g. using a large roof overhang, and that considerable maintenance will be required after the rainy season.

The benefits of applying rendering were clear. All rendered walls were intact after the rains and showed negligible surface erosion. The cement rendering appeared to be in extremely good condition. Small holes had however formed in the soil/bitumen rendering; water appeared to have entered through these and there was evidence of erosion behind the rendering. It is likely that the soil/bitumen rendering would start to fail during the next rains, requiring maintenance using a soil/bitumen slurry applied to areas of deterioration. The cement rendered silos will need similar maintenance though, given their state of repair, this should be required less often.

ANOVA was applied to the average roughness figures taken over the last five months of the trial (treatment A was left out as these replicates had collapsed). Table 18 shows the means for each treatment.

Table 18 Mean roughness over the last five months of the mud durability trial. S.e.d. between any two means = 0.97 cm.

Treatment	Mean roughness (cm)
B	5.0
C	4.5
D	4.4
E	2.3
F	1.6

There was a significant difference due to the treatment ($F_{(4,10)}$ = 5.0, P = 0.018). A contrast between the rendered and unrendered treatments, i.e. the average of E and F against the average of B,C and D, showed that the rendered walls remained significantly smoother (t_{10} = 4.3, P = 0.002). There were no significant effects due to the addition of Beini or Dawa-dawa to the mud/grass mixture, or between the two rendering methods. This supports the conclusion above that there was little difference between the three unrendered treatments, but that the two rendered treatments remained in much better condition.

The overall conclusions are therefore that:

- it is essential to add grass to the mud mixture;
- the Beini and Dawa-dawa treatments gave no improvement to the mud/grass mixture;
- rendering significantly improved the durability of mud/grass mixtures, with cement appearing to be the most durable rendering method;
- protection of the silos from the rain, combined with regular maintenance and repair are important.

<u>**Chapter 6**</u>

FUMIGATION OF MUD SILOS

Two trials were established in which the mud silos at SARI (those used for the environmental monitoring trials, Figure 1) and fired-clay water pots were fumigated with phosphine gas. The water pots were used to test the effectiveness of different surface treatments on gas tightness – pots were used for experimental purposes instead of mud silos since the variability between different pots was far less than that between different mud silos.

The objectives of the two trials were as follows:

- Fumigation of the same silos as those fumigated two years previously (as part of A0419 *Improving the use of phosphine for small-scale fumigation of grain on farms in Ghana*) to determine whether the degree of gas tightness of the silos had deteriorated with time.

- Effectiveness of polish, paint and varnish treatments on the gas tightness of new fired-clay water pots.

Silos/pots were initially inspected for any damage, in particular cracks – any damage was repaired prior to the trial. Nylon gas-sampling lines were inserted into each of the silos/pots, phosphine gas producing tablets were added and the silo/pot sealed by securing a plastic sheet over the opening using adhesive. Gas concentrations were monitored using a Bedfont EC80 phosphine meter each day for the following five days. Concentrations were plotted against time – a fumigation being deemed as having succeeded if the concentration remained in excess of 150ppm by the end of the fifth day.

RESULTS

The gas tightness of the mud silos had deteriorated over time. Initial fumigations to the silos following what would be the ‘normal’ degree of maintenance expected (i.e. repair of any visible cracks in the silo walls) produced very poor results - almost total gas loss within the first 1 to 2 days compared to a minimum 5 day exposure period required for a successful fumigation. Silos were then re-rendered and repainted and fumigated once more – although some silos were now deemed to be sufficiently gas tight, great variability existed between individual silos.

Water pots were either polished, painted or varnished on their outer surfaces before being fumigated – although some success was achieved, 10 of the 20 pots failed to provide sufficient levels of gas tightness. No difference between the treatments were apparent. The outsides of the pots were then retreated, and inside surfaces also treated before being fumigated once more. Although very high concentrations were achieved in some of the pots, many of the pots still failed.

The costs of fumigating with phosphine were compared to the use of insecticidal dusts. Without modifying the silos, fumigation is much cheaper than the use of an insecticide. However, with the sealing applied during the trials (sealing of plastic sheeting over the upper opening of the silo) there is little difference in cost between the two methods.

CONCLUSIONS

Traditional small-scale storage structures of the type found in northern Ghana are totally unsuitable for fumigation purposes. Even under strict experimental conditions where the standard of treatment application would be much higher than that expected in the field, it was not possible to guarantee success.

Given the proximity of many of these storage structures to the living quarters, in many cases stores are actually contained in the living quarters, the uncontrolled loss of gas poses very real safety concerns.

The likely failure of most, if not all of the fumigations, also poses the very real threat of developing phosphine-resistant strains of insects within Ghana. Should this occur, then food security throughout the country could be placed under severe risk since the main pest control treatment of larger stocks of grain (i.e. phosphine) could become ineffective.

The overriding conclusion therefore should be that all efforts should be made to discourage the use of phosphine fumigation at the small-scale farmer level. Alternative, preferably traditional treatments should be assessed and the most promising ones promoted.

Chapter 7

OVERALL DISCUSSION

Results from the physical comparisons show that the Kambong stores were cooler than the mud silos and had lower moisture contents during and at the end of storage. The reason for this may be that the Kambongs are better ventilated than the mud silos: external air can alter the temperature and moisture content more rapidly. In the case of the moisture content, the ambient conditions were such that they caused drying at first then wetting during the rainy season. To avoid the risk of mould growth, maize needs to be dried to around 11% for the mud silos and around 12% for the Kambongs (compared to moisture contents of between 13% and 14% as recorded at the beginning of the trial). This last point is extremely important since without adequate drying prior to storage, the mud silo is not suitable for grain storage due to the inability of high humidity air to escape from the sealed structure. However, with adequate drying the mud silo can perform well as a store since the solid walls may act as effective barriers against secondary insect infestation.

The mould analysis, combined with visual observations of the grain during unloading, showed that mould growth had occurred during storage, with species associated with poor storage conditions occurring after storage. However, the heavy initial infection of the maize and its high aflatoxin content made it impossible to judge the relative performance of the store designs. The Kambongs proved to have the highest percentage infection by *Aspergillus flavus* and the highest aflatoxin content after storage. Further work will be necessary to clarify this issue. There appears to be a correlation between gaps in the tops of the silos and mould growth in this area, therefore mud silos need to have a gap under the lids to avoid this.

All stores became infested with a range of insect species and it cannot be concluded that any design was better or worse, though the insect spectrum varied between store types. The level of infestation was reflected by the extent of insect damage found in the grain after storage, which was no different between store types. It may be concluded that effective insect control techniques will be needed whichever store is used.

The carbon dioxide concentrations showed no differences between the rendered and unrendered mud silos: both retained much higher levels than the Kambongs, presumably due to the better ventilation of the latter. The source of the carbon dioxide could have been from the mould growth that occurred during storage, or from the insect infestations that had developed. Although relatively high concentrations were noted, these were insufficient to kill insects although they may have had an effect on rates of insect growth.

The mud durability trials showed that grass is an essential ingredient of any mud wall, that incorporating Beini and Dawa-dawa had no effect, and that rendering was very effective in maintaining the mud walls, with cement seeming to be the most durable. Thus rendering, and the need for regular maintenance, can be recommended.

The termite trials were inconclusive. Although certain treatments (using either physical barriers or chemical treatments) were found to be more effective than others, this is an important area of concern, and further work needs to be undertaken to develop effective and safe control techniques.

The PRA survey indicated that there is little gap between reality and expectation of the effectiveness of mud silos. The interest of non-users of mud silos was found to be influenced directly by the expectations of the effectiveness of mud silos and their actual performance reported by their colleagues. For all communities surveyed, the evidence of interest of non-users of mud silos was quite high, and this confirms the premise that if the gap between reality and expectation is small, farmers will be enthusiastic and willing to pay for mud silos.

Important concerns that came up during discussions and were expressed by farmers were:

- **timing of construction**: farmers said sending builders to them soon after harvest, rather than late in the dry season, would enable them to store effectively, and would not coincide with early rains;

- **training**: farmers said it would be very helpful to train many more builders (about 20 builders per village) so that the constraints of skilled labour will be reduced.

- **knowledge of maintenance**: farmers said they are not satisfied with their knowledge of how to protect and maintain mud silos. Training should be provided;

- **flexible packages**: at present, only farmers in villages where MoFA and ADRA work have access to mud silo builders. Farmers said the technology should be extended to other villages.

A number of changes need to be made to the policies and planning of extension packages promoting the adoption and use of mud silos in order to facilitate the process:

- packages should be extended and expanded to cover many more communities in order to achieve a critical mass, and should not be targeted only on farmers participating in MoFA/ADRA projects;

- packages should make provision for mud silo builders to spent more time in villages, and should also include the training of local beneficiaries (farmers in their own settings) in the construction and maintenance to remove the constraints on skilled labour;

- if packages are to be extended or expanded, the involvement of local NGOs should be encouraged as this will reduce the burden on MoFA which is already constrained in terms of manpower;

- above all, packages should be flexible enough to allow for various and different modes of repayment of credit and other inputs.

The survey revealed that there is insufficient information and knowledge about farmers' storage behaviour. Much of the previous work has been targeted at technical issues relating to post harvest handling and storage of agricultural produce, while little or nothing has been done to identify characteristics of farmers that influence their storage behaviour.

Further research is needed into the availability of the different types of construction materials, and the technical effectiveness of these materials.

The issue of 'good' and 'poor' storage hands, which recurred throughout the survey, should not be discarded as myth. Further investigations may identify farmers' behaviour and techniques which have a positive or negative impact on storage. A better understanding of the belief itself would allow extension packages to take it into account with the necessary sensitivity.

REFERENCES

Brice, J, Moss, C. Marsland, N. Stevenson, S, Bediako, J Gbetroe, H Yeboah, R and Ayuba I, (1996) Post-harvest constraints and opportunities in cereal and legume production systems in northern Ghana. RNRRS Technical Report, NRI Project Nos. A0493, A0494, A0495.

Brice, J and Ayuba (1996) Improving the use of phosphine for small scale fumigation of grains on farms in Ghana. RNRRS Technical Report, NRI Project No. A0419.

Golob, P. Stringfellow, R. and Asante E.O. (1996) A Review of the storage and Marketing Systems of Major Food Grains in Northern Ghana. NRI Report.

Gudrups, I. Asante E. O. and Bruce, P (1995) Survey of the use of Pulses within Ghana. NRI Report R2232 S.

Millar, D. (1996) Footsteps in the mud: reconstructing rural peoples' knowledge. PhD Dissertation. Wageningen University.

DISSERTATION OUTPUTS

Brice, J. and Ayuba, I (1996) Environmental monitoring trials in mud silos – February to November 1996. NRI Report No. R2356(S).

Brice, J. and Golob, P. (*in prep.*) Fumigation using phosphine in mud-built, farmer level stores in northern Ghana.

Brice, J.R., Moss, C., Marsland, N., Stevenson, S., Fuseini, H., Bediako, J., Gbetroe, H., Yeboah, R. and Ayuba, I. (1996) Post-harvest constraints and opportunities in cereal and legume production systems in northern Ghana. NRI Report No. R2461.

Mitchell, M. (1997) Report on a visit to northern Ghana to advise on the protection of farm storage structures against termites. NRI Report No.2460.

ANNEX 1 SUMMARY OF FINDINGS FROM THE 1996 PRA SURVEY

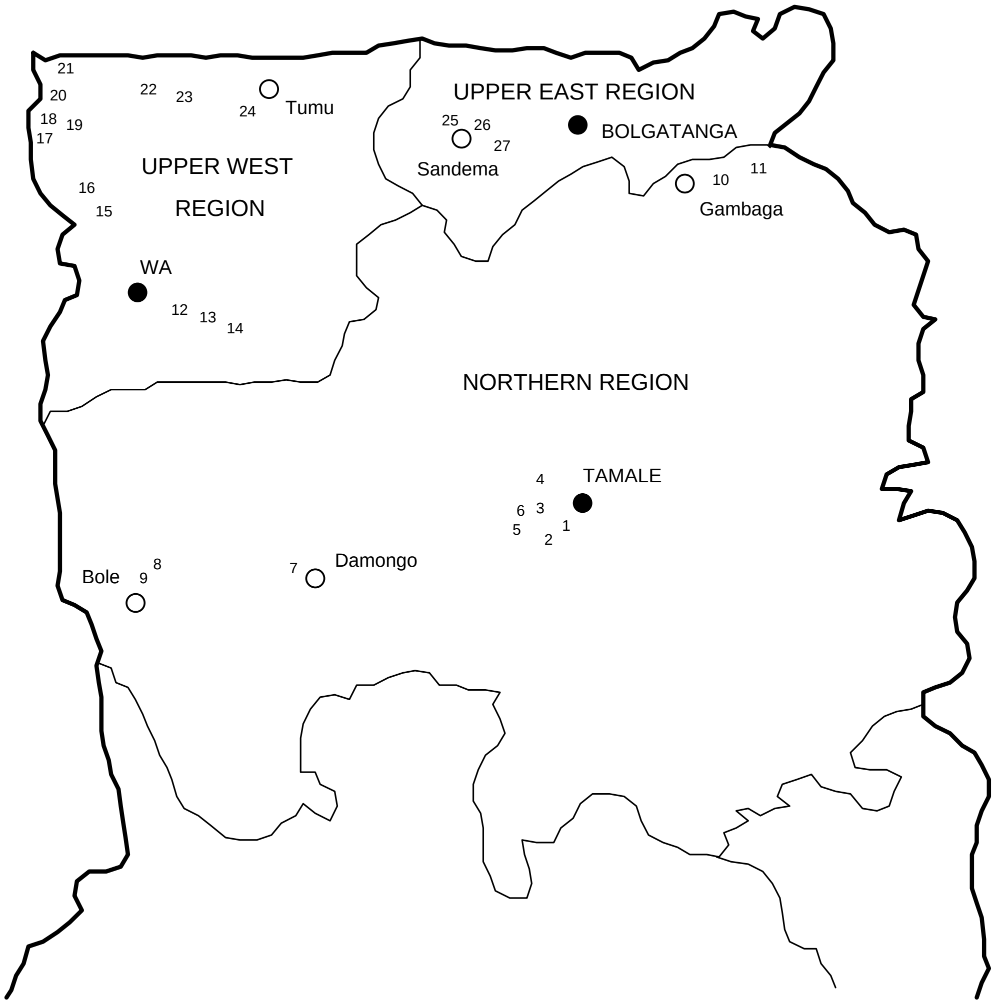

Figure A1.1 Villages visited during the 1996 PRA survey

Table A1.1 Storage structures used throughout northern Ghana

Code	Store Type	Local name	Village	Description
A	Mud silo 1 (**BIMOBA**)[a]	no name Bule Lipil Buga[b] Bugi[c]	2, 3, 4 5 7 10, 11 11	Spherical shape on three or four legs (as introduced by MoFA)
B	Mud silo 2[a]	Bui Tula **BAARE** Baari Bood Bwr	19 20 20 21 22 23	Cone shaped, built on a layer of stones and/or poles. Free-standing outside of any other structure.
C	Mud silo 3[a]	Katari[d] Bowr[e] Bowryari[e] Vuri[f]	12 12, 17 12	Square or circular, built within a room (or under a flat roof), tapering to a neck protruding through the roof (access via the roof)
D	Mud silo 4[a]	Namvuri[g]	14, 16	Usually rectangular, outside of the house, floor raised 0.5m above the ground (with fowls below), made from bricks, up to 3m tall.
E	Mud silo 5[a]	Buo Katanga (larger Buo) Bowrpla	13 13 17	Small, often egg shaped, usually portable store. Often sealed at the top with a small opening in the side.
F	Wooden framed, thatched	**KAMBONG** Kpacharaga Chenchunkum Chenchenlenkung Napoo Sigi Brugu Ganga[h] Pulu Narpaug	1, 2, 3, 5, 6 4, 6, 7 6 7 8 10 11 13 16 23	Wooden frame work with 'Zana' matting (woven sorghum matting) floor and walls. Floor traditional ½m off the ground (MoFA 'improved' Kambong is raised 1½m above the ground for improved rodent resistance)
	Floorless, wooden framed, thatched	Sogli	6	Same as Kambong but without a raised floor (produce stored on the ground)
	Conventional hut	Libuul	7	Same as the hut in which the villagers live
	Small hut	Napogu	6	Small mud hut with raised platform, covered with Zana matting
G	Raised Platform	**LINGA** Kikaafil Capala[h]	1, 3, 5, 6[i], 8 7 10	Platform made from wooden poles (often with matting from sorghum stalks), raised 1½ to 2 metres from the ground. Area underneath often used as a shaded meeting place.
H	Baskets: (i) Unplastered	 **KUNCHUN** Chenchunkum Napogu Pege Sampaa(?) Yikori Koyonko	 1, 3, 7, 8 2 2, 4 11 13 19 21	Basket made from sorghum stalks. Usually placed on a raised platform or Linga. The name usually describes the basket itself (which is then placed on a Linga) but occasionally the name indicates the whole thing (including the Linga). Sometimes there are separate names for those plastered with cow dung and those that aren't. Other

		Naparg[j]	22	times the same name is used whether or not it is plastered. Baskets usually plastered when storing smaller grains such as millet and sorghum (or for insect control?).
	(ii) Plastered	Chenchunkum Pupuri Kunchun (Kupong) Kosorgu Yikori	1, 2, 5[k] 2, 4, 5[l] 6[I] 13, 23 19	
	Temporary structure	Sinklepohingu	8	Boat-like structure made from ropes and grass
I	Fired clay pots	most villages Singi Simme Dugu Vijen Dokoh Yor (small) Duk (large)	 11 12 13 14 21 22 22, 23	
	Enclosed raised platform	Seri[m] Yam barn (Pilawe)	12 14	
J	Jute sacks		2, 4, 6, 8, 10	
	Bottles		22	Glass bottles for thermal disinfestation and storage of seed

Villages: 1 to 5: Tamale area; 6 to 8 eastern NR; 9 to 12 western NR; 13 to 18 UWR; 19 to 23 UER.

[a] Another advantage with the mud silo is the confidentiality - people don't know how much you have (village 8).
[b] Buga have no compartments whilst the Bugi[c] have compartments
[d] Outside, under a Linga type roof
[e] Both are inside the room, the Bowryari has one compartment whilst the Bowr has several (also totally inside including the opening).
[f] Vuri is the general name for the mud silo - Bauvuri (large Vuri), Mamvuri (small Vuri)
[g] The Namvuro is made from mud bricks and for this reason is less sturdy than the mud silo (village 15)
[h] On farm storage structures as opposed to in the living compound
[i] A Kunchun placed on a Linga is called a Kupong in village 6
[j] Large container rather like a Kambong but without the wooden supports therefore classed as Kunchun
[k] Used for large quantities of rice, compared with [l] for small quantities of rice (different names for smaller and larger structures of the same type)
[m] Linga with closed sides in which yams are stored

ANNEX 2 SUMMARY OF FINDINGS FROM THE 1999 PRA SURVEY

Table A2.1 List of villages visited during the survey, number of respondents, and percentage and frequency of users of mud silos

No.	Village	District	Ethnic Group	Category of Farmers				Farmers using mud silos	
				1	2	3	4	Percentage	Frequency
1	Mbanaayili	Tolon-Kumbungu	Dagomba	13	12	7	17	15	1
2	Cheshegu	"	"	2	8	5	7	3	1
3	Cheyohi	"	"	2	10	1	12	5	1
4	Gbullung	"	"	15	12	6	15	12	1
5	Tampe-Kukuo	"	"	2	3	2	5	3	1.2*
6	Nafarung	"	"	8	7	10	11	14	1
7	Tuunaayili	"	"	3	3	4	7	2	1.5
8	Fazihini	Savelugu Nantong	Dagomba	14	18	12	23	13	1
9	Kparigulanyili	"	"	10	12	17	21	10	1
10	Sahanaayili	"	"	6	11	9	13	12	1
11	Naplesi	"	"	7	9	5	12	8	1
12	Kanshegu	"	"	3	6	3	9	16	1.05*
13	Sankpagla	Damongo	Dagomba & Gonja	5	3	10	11	5	1
14	Jaramoayili	"	Dagomba & Gonja	4	4	3	12	7	1
15	Aliyili	"	Dagomba & Gonja	2	9	3	9	3	1
16	Mpaha	"	Gonja	17	12	13	23	10	1
17	Sheeri	"	Gonja	6	4	5	12	8	1
18	Kpabusu	"	Gonja	6	3	11	9	6	1
19	Kalande	Salaga	Gonja	9	6	7	5	25	1.1*
20	Bunjai	"	Dagomba & Gonja	6	12	8	7	13	1.6*
21	Kabachie	"	Dagomba & Gonja	5	10	11	12	12	1
22	Massaka	"	Dagomba & Gonja	6	12	4	3	15	1
23	Bakpaba	Bimbilla	Nanumba & Konkomba	4	13	5	6	8	1
24	Bincheratanga	"	Nanumba & Konkomba	13	18	12	11	18	1
25	Makayili	"	Nanumba & Konkomba	4	2	6	7	2	1
26	Demon-Nayili	"	Nanumba	12	17	15	13	12	1
27	Kpabi	"	Nanumba & Konkomba	11	10	17	9	10	1

28	Kabonbu	Saboba-Chereponi	Konkomba	23	4	7	4	90	3.1*
29	Kumateek	“	“	15	7	9	10	88	2.8*
30	Tchaabob	“	“	12	3	11	11	65	1.6*
31	Nakpale	“	“	26	12	12	8	80	2.6*
32	Jilima	“	“	0	18	0	4	0	0
33	Nakpambori	“	“	0	15	0	8	0	0
34	Nankpang-ni	“	“	0	22	0	4	0	0
35	Waabul	“	“	0	17	0	10	0	0
36	Naajong No.1	East Bimoba	Bimoba & Talensi	28	3	12	14	70	2.8*
37	Chentlung	“	Bimoba	24	7	16	11	70	2.4*
38	Jilig	“	Bimoba	20	4	10	17	65	1.8*
39	Bunkpurugu	“	Bimoba & Kusaasi	16	3	7	9	30	1.2*
40	Kinkanwu	“	Bimoba	8	2	5	6	75	1.5*
41	Langbensi	“	Bimoba & Mossi	6	8	3	2	10	1
				373	371	303	419		

Note: * In the Table above, the total farmer population was taken from the Assembly man of the community. In villages 5, 7, 12, 19, 20, 28 -31, 36 - 40, the exact number of farmers was not readily known, and respondents had to estimate the figure.

The ‘frequency’ of mud silos refers to the number of mud silos owned and used by one farmer in any particular community.

Table A2.2 Types of material used in mud silo construction mentioned by farmers

Group	Dagbani name	Gonja name	Nanumba name	Konkomba name
<u>EARTH MATERIALS</u>				
Termite hill (recent)	Yab-li, yab-zie	Ki-shibile	Yob-li, yob-zie	Li-dipa
Termite hill (old)	Dig-li	Kab-or	Dig-li	Ti-yar
Loamy subsoil	Gben-gbeli	*not mentioned*	Gbeli	*not mentioned*
Pottery clay	Yag-ri	*not mentioned*	Yog-ri	Li-yar
Alluvial clay	Ba-yagri, ba-pielli	*not mentioned*	Ba-pielli	Ti-kpakpar
<u>GRASS MATERIALS</u>				
Reddish-brown grass	Mo-mang-li, Ba-mogu	Atem-bo	Mo-ziegu Mo-laa	N-tuom
Pearl millet grass	Chima	Achalabe	Chima	*not mentioned*
Hyena grass	Kundung-piem	Moa-le	Kundung-piem	Ti-guri
Rice straw	Shinkafa-mori	Sinkafa	Sinkafa-mogu	*not mentioned*
Any light grass	Mo-furi, Dazie-mam	Efun-ting	Mo-fugu	Ti-puikakan *(Digitaria spp.)*
<u>SLIME MATERIALS</u>				
Root & Stem of plant	Bie-ni	Chakpa	Yenni	Li-dign
Root of plant	Yal-ga	Furibi	Yol-ga, Yel-gili	N-yue
Okro sticks	Maan-dari	*"Okro sticks"*	Maan-dagu	*not mentioned*
Baobab bark	Tua	*not mentioned*	*not mentioned*	*not mentioned*
Other plants	Jaa-li, zollima, piegu-nyamari	Gbugbula furibi	Bulumbugu, buun-saligu	*not mentioned*

Table A2.3 Types of crops stored in structures

Type of structure	Crops stored	Form of produce	Length of storage	Conditions/Remarks
Kambong[1]/ Kpachagriga/ Kachala	all cereals, groundnuts, bambara nuts, cowpeas, beans.	sun-dried, unthreshed, or unshelled	less than 3 months	rodent and insect damage, prone to fire, theft, and rain.
	dried peeled cassava (konkonte)	peeled and dried pieces	up to 6 months	rodent and insect damage, prone to fire, theft, and rain.
Chenchenkung [2]/ Chenkung	all cereals, groundnuts, bambara nuts, cowpeas, beans.	sun-dried, unthreshed, or unshelled	less than 3 months	rodent and insect damage, prone to fire, theft, and rain.
	dried peeled cassava / konkonte	peeled and dried pieces	less than 6 months	rodent and insect damage, prone to fire, theft, and rain.
Leenga[3]/Linga	all cereals (except maize), cowpeas, beans.	sun-dried, unthreshed, or unshelled	less than 3 months	rodent and insect damage, prone to fire, theft, and rain.
	konkonte	peeled and dried pieces	less than 3 months	rodent and insect damage, prone to fire, theft, and rain.
Napogu[4]/ Napoo/ Napaugu	all cereals except maize, cowpeas, beans.	sun-dried, unthreshed, or unshelled	up to 6 months	rodent and insect damage, also damage from moulds
	konkonte	peeled and dried pieces	more than 6 months	rodent and insect damage, also damage from moulds
Kunchung[5]/ Kulunchung	all cereals, groundnuts, bambara nuts, cowpeas, beans.	threshed or shelled cereals, unshelled groundnuts, bambara nuts, cowpeas, beans.	more than 6 months	rodent and insect damage, also damage from moulds prone to theft, rain and fire.
	dried peeled cassava / konkonte	peeled and dried pieces	more than 6 months	rodent and insect damage, also damage from moulds prone to theft, rain and fire.
Buli[6]/ K'puri/ K'dondongne/ Lipil/ Buar (Bimoba)	all cereals, groundnuts, bambara nuts, cowpeas, beans.	threshed, or shelled cereals, unshelled groundnuts, bambara nuts, cowpeas, beans.	more than 12 months	protected from rodents, insects, theft, rain and fire.
	dried peeled cassava / konkonte	peeled and dried pieces	up to 12 months	protected from rodents, insects, theft, rain, and fire.

[1] Wooden frame with 'zana' matting (woven sorghum matting) floor and walls. Traditional Kambong is raised half-metre above ground, MoFA 'improved' Kambong is one-and-a-half metres above ground.
[2] Basket made from sorghum stalks, placed on a raised wooden platform, and covered with thatch, usually located outside the compound.
[3] Platform made from wooden poles (often with matting from sorghum stalks), raised about 2 metres from the ground. Area underneath often used as a shaded meeting place.
[4] Small mud hut with raised platform, roofed with thatch. Area below platform often used as hen coop.
[5] Large basket woven from sorghum stalks and plastered with cow dung. Usually placed in sitting halls (without thatch roof) on stones, or in the compound on stones and roofed with thatch.
[6] Large spherical unburned mud pot with an opening at top sufficient to allow passage by an adult, resting on one, three or four large stones. Usually constructed with a collar (band of mud) round the middle of the exterior used as support when entering or exiting the mud silo.

Table A2.4 Life span of structures encountered during survey

Storage structure	Principal materials	Life span
Kambong/ Kpachagriga/ Kachala	Wooden poles, 'zanamat' grass, and thatch	up to 10 years when well maintained
Kunchung/ kulunchung	guineacorn stalks, cow dung, and thatch	10 to 15 years when well maintained
Leenga/Linga	wooden poles and rafters, and 'zanamat' grass	more than 25 years when well maintained
Mud silo/ buli/lipil/k'puri	reinforced mud, thatch	more than 40 years

Table A2.5 Storage length of produce before significant deterioration

Structure	Crops stored	Length of storage
Kambong/ Kpachagriga/Kachala	all cereals, groundnuts, bambara nuts, cowpeas, beans, konkonte.	less than 3 months
Chenchenkung/ Chenkung	all cereals, groundnuts, bambara nuts, cowpeas, beans, konkonte.	between 3 - 6 months
Leenga/Linga	all cereals except maize, cowpeas, beans, konkonte.	less than 3 months
Napogu/ Napoo/ Napaugu	all cereals except maize, cowpeas, beans, konkonte.	up to 6 months
Kunchung/ Kulunchung	all cereals, groundnuts, bambara nuts, cowpeas, beans, konkonte.	up to 9 months
Buli/ K'puri/ K'dondongne/ Lipil/ Buar	all cereals, groundnuts, bambara nuts, cowpeas, beans, konkonte.	more than 12 months

Table A2.6 Effectiveness of structures in protecting stored produce

Storage structure	Protection against insects	Protection against rodents	Protection against rain	Protection against fire	Protection against theft
Kambong/ Kpachagriga/ Kachala	low, grass harbour insects	low, rodents can chew through walls	low, rain can penetrate its walls & roof	very, very low. fire consumes grass and wood	low, structures are normally erected outside the yard
Chenchenkung/ Chenchelenkung	low, but better than Kambong	medium, due to raised platform	very low, rain can penetrate wall and roof	very, very low. fire consumes grass and wood	low, but less accessible than Kambong
Leenga/ Linga	nil, too exposed	low, rodent can climb poles	nil, too exposed	low, due to raised platform	nil, too exposed
Napogu/ Napoo/ Napaugu	medium, insects can only penetrate roof not walls	poor, mostly rodents breed in Napogu	high, walls and roof keep out rain	medium, only roof can be consumed by fire	high, produce is not easily accessible even to owner
Kunchung/ Kulunchung	medium, cow dung is used to close any gaps and openings	low, rodent can chew through walls and roof	medium, rain rarely penetrates walls or roof	very, very low. fire consumes roof and walls	medium, sides can be punctured and produce can be drawn by gravity
Mud silo/ Buli/ K'puri/ Lipil/ Buar	high, insects cannot penetrate walls	high, rodents cannot penetrate walls	high, rain can not penetrate walls and roof	high, fire can consume only roof	high, produce is not easily accessible to even owner

Table A2.7 Resistance of structure to causes of damage

Storage structure	Resistance to damage by termite attack	Resistance to damage by rodents	Resistance to damage by rain	Resistance to damage by fire	Resistance to roaming cattle
Kunchung/ Kulunchung	- medium, - placed on stones or raised platform, termite attack is not easy to monitor under the structure	- low, - rodents can chew away at the walls and roof of structure	- medium, - rainstorms can penetrate walls or roof when not placed in a room	nil, - fire can consume the whole structure	- low, - the whole structure can be destroyed by cattle
Mud silo/ Buli/ K'puri/ Lipil/ Buar	- high, - regular monitoring for termite attack can be easily done - ash or discarded engine oil from cornmills or tractors can be applied on ground under and around the structure	- high, - rodents cannot destroy or penetrate walls	-medium, - rainstorms can affect walls - roof can leak when not thatch is not right quality.	- high, - fire can consume only roof if not very intense	- high, - cattle cannot push down structure even when empty

Table A2.8 Summary of costs of constructing mud silos of particular capacities

District	Capacity of mud silo (maxi-bags)	Material costs (cedis)	Labour costs (cedis)	Workmanship (cedis)
Tolon-Kumbungu	5 - 7 bags	10,000	25,000	40,000
	10 -15 bags	20,000	30,000	50,000
Savelugu-Nantong	5 bags	5,000	10,000	20,000
Damongo	5 bags	10,000	20,000	25,000
	10 bags	25,000	30,000	50,000
Salaga	5 - 6 bags	5,000	15,000	20,000
	10 bags	5,000	30,000	40,000
Bimbilla	15 bags	10,000	30,000	40,000
	5 - 7 bags	3,000	10,000	15,000
Saboba	30 bags	10,000	30,000	64,000 or 20,000 per footing
East Bimoba	5 bags	4,000	10,000	10,000
	10 -12 bags	6,000	20,000	12,000
	15 - 20 bags	10,000	25,000	16,000