INTERNATIONAL COURSE IN FOOD SCIENCE AND NUTRITION
"RURAL FOOD TECHNOLOGY"

DRYING AND STORAGE SYSTEMS FOR MAIZE AT FARM/VILLAGE LEVEL; A CASE-STUDY MODELLED IN S.W. NIGERIA

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The Netherlands
Wageningen, June 1980

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FOREWORD

This report is based on a group research project carried out by a group of participants of the eleventh International Course in Food Science and Nutrition held in Wageningen (January - June 1980) under the theme "Rural Food Technology - Its Impact on Food Availability, Food Storage, Processing and Nutrition."

The project formed part of the training programme aimed at demonstrating the importance of a problem approach that takes into account the social and cultural factors as well as technical and economical factors involved in the choice of technology.

Drying and storage systems for maize at farm/village level as given in this report was chosen because of the importance of drying and farm storage in the post harvest sector in developing countries. Grain drying in hot humid climates is an important but difficult process. Failure to dry damp or moist grain can result in severe loss by moulds and insects. Farm storage is used to protect almost all grain produced for some period of time; essentially all of the seed supply and moist of the non urban food supply is entirely dependent on farm storage.
Current farm structures provide functional storage using local materials and skills. For this reasons the farm facilities must be recognized in the application of sound storage principles and pest control measures in order to reduce losses. The main part of this report is presented in the form of feasibility study, where the comparison is made between extension and artificial dryer aiming to prevent losses. Due to the time limit, some of the steps in the feasibility study is given in the form of a checklist.

ACKNOWLEDGEMENTS

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SUMMARY

An inventory of drying and storage systems for maize in the humid tropics showed that there are two main types of traditional structures, one with solid walls found in the dryer areas, where a distinct dry season follows the drying of the crops and one with open sided walls that allows free movement of air through the crop, in more humid areas. Each of these structures can store products successfully if minor modification are made on them.

The main problem found in the model country (s.w. Nigeria) is drying of maize. The farmer can solve this problem by leaving his crop in the field to dry to the required moisture levels of about 18 to 20%. This process exposes the crop to high field infestation resulting in high storage losses of of about 12.3% insect damage 10.2% fungal growth and 5.7% weight loss. Improvements on storage have shown the above percentage losses can be reduced to 5.6% for insect damage, 5.3% for fungal growth and 0.3% for weight loss.

Maize can be harvested at moisture content above 20% and dried within a period of 10 days by the use of artificial dryer. Alternatively improvements can be done on already existing traditional drying and storage structures by the use of extension service.
Comparison between the two alternatives was done in a form of a feasibility study. Based on above information of losses, benefit-cost (B/C) ratio worked out as 0.56 for extension service and 0.73 for a dryer. The discount factor at 12% was used in calculating the B/C ratios. The B/C ratio is valuable in comparing the two alternatives because the benefit are the same. Both projects are not cost-covering and it seems that the dryer is more profitable than the extension programme. However on the long run the benefits for the farmer are 1,5 times larger than the costs in the case of an extension programme, therefore this project is recommended by the team.

I. INTRODUCTION

I-1. Background of project

Food availability in any given country or society could be assured by increase in production, coupled with good storage and preservation. In most developing countries considerable portions of crops are lost to insects, birds, rodents, micro-organisms especially fungi, before they are ever harvested and further losses occur all along the chain of food handling from the time the crops are harvested, processed and marketed. It is now being increasingly realized that reduction of these losses offers a major possiblity to increase the availability of food both at national and household levels.
Throughout the world cereal grains are the main source of food, and in the developing countries comprise 80 to 90 per cent of the diet. One of the important cereals consumed in these countries is maize.
Maize or corn botanically known as Zea mays (Linnaeus) is grown in more developing countries (100) than any of the other cereals such as rice, wheat, sorghum, millet and balley (GASGA, 1978). Maize cultivation is thought to have started in America (Carribean) in about 80.000 years ago (Walden, 1966) from where it proliferated to different parts of the world by means of trading. The period of flowering and maturity varies greatly according to variety and altitude. At low altitudes, short maturing varieties flower in two months and mature in four months.
The grain is physiologically mature when it accumulates no more dry matter when it contains 30 to 35 per cent moisture, it is harvested with a moisture content of about 20-25%, depending on the environmental weather.
After harvest, it must be dried further up to a safe storage moisture content of about 12 to 13%. In rural areas, there are mainly two sources of drying, namely sundrying and fuel based drying. Sundrying is normally done after harvesting, but sometimes drying may commence before the crop is harvested. In certain areas maize is left standing in the field for few weeks after maturing to attain a moisture content of about 18% before harvesting. Further drying is facilitated during storage in specially designed structures. The type of structures used for drying and/or storage vary with climate and socio-economic conditions but, basically the stores can be divided into two main categories: The open sided cribs found in hot humid areas where there is usually a short dry spell between the rainy seasons and the solid walled granaries found in dryer areas, where a distinct dry season follows the harvesting of the crop. A summary of drying and storage systems for maize is given in Table I in Appendix I.

I-2. Model Country

We have chosen South Western Nigeria with a hot humid climate in the lowland forest zone of Nigeria as our model area of study because information is available in the literature for this region.
South Western Nigeria is an important maize producing area in Nigeria. It has two rainy seasons in the year. The first rains fall in April to July followed by a brief dry spell in July/August after which the second rains fall in August to November.
Temperatures are usually in the range of 24°C to 35°C (Oyenuga, 1967). Humidities are fairly high with an average monthly range of 60 to 80 per cent. Highest average monthly relative humidities are found in September to October and lowest in December to February. The major maize crop is ready for harvesting in July/August coinciding with a brief but rather unreliable dry spell between the two rainy seasons. Farmers in this region, harvest the maize crop when the moisture level is about 18 to 20 percent and store in the traditional freely ventilated stores.

I-3. Problem formulation

The open sided traditional structures used in West Africa in general allow maize of relatively low moisture content of 18 to 20 percent to be stored in them. This means that the farmer in this region cannot remove his crop from the field until it has reached this moisture content or level. But in south West Nigeria where there is a short dry spell between the two rainy seasons, farmers are faced with a critical timing in harvesting and drying of the crop. Recent investigations in Nigeria (Boshoff, 1977) recorded insect damage of 12.3%, 10.2% fungal damage and a weight loss of 5.7% of the maize crop left in the field against 5.6%, 5.3 and 0.3% respectively, for insect damage fungal damage and weight loss of maize harvested immediately after ripening and stored in improved narrower cribs for the same period of 7 weeks.
There are two alternatives to the solution of the drying problem and hence reduction of losses. The first one is the introduction of an artificial dryer, * farmers ~~on~~ how to improve their storage structures such that maize of higher moisture content can be stored in them. In the choice of the alternative to solve the drying problem, the following limitations must be taken into account.

1. The innovation must make use of locally available skills.
2. It must make use of locally available materials.
3. It must be acceptable to the farmers.
4. It must be relatively cheap.
5. It should make use of renewable natural resources e.g. Building materials such as wood.

I-4. Terms of reference

The Government of Nigeria, recognises that a post-harvest loss problem exists in Nigeria and are committed to dealing with it. The Governments' Ministry of Agriculture has requested the assistance of the project team acting as a group of consultants on post-harvest systems to advice on reduction of post-harvest losses of maize, in a village of South Western Nigeria with 100 farmers. The following terms of reference have been agreed on:

1. The team will study the national post-harvest system for maize.
2. The team will investigate and quantify the post-harvest losses.
3. Where information is lacking, the team will carry out loss assessment survey to quantify losses and hence identify the area for loss reduction activity.
4. Where necessary laboratory and pilot scale research will be included to investigate specific aspects of proposals.
5. The team will make recommendations for specific proposals for loss reduction based on socio-economic and benefit-cost decisions regarding the resources required to reduce losses.

* the second is the use of an extension service to teach ....

II. SOCIO - ECONOMIC SURVEY

In any given situation the introduction of an innovation needs a careful consideration . The culture social and economic set up of the people to be reached should be well understood. The aim of this survey was to find out how farmers in the mentioned area live. The type of problems the farmers have and the ones they think to be of immediate importance. In addition to this there is need to gather information on how the farmers distribute their work load in the village. It is important to gather information on how the innovation is going to benefit the farmers, both socially and economically. The social cultural practices of the area have to be taken into account.
The introduction of improved methods of drying grain is expected to reduce losses and hence make more grain available to the farmer and the society as a whole consequently on increase in farmers food supply, nutritional status, ~~and~~ income and purchasing power.
The above information is more of a checklist of what would have been gathered in a real feasibility study. But due to limited time it was not possible to carry out a complete feasibility study.

III. LOSS-ASSESSMENT STUDY

III-1. Identification of losses in the food pipeline

Before a loss reduction programme is established, basic information on post-harvest losses must be obtained. This information should include the whole post harvest system or that part of it which will be affected by any proposed changes. Accurate information not only about the magnitude of the losses, but also the range between operators and between years is essential in establishing programme priorities for practical and continuing improvements to be developed and instituted.
For the purpose of identifying loss points which are critical and amenable to reduction, the following pipeline concept is used to describe the location and flow of grains. (See fig. 1)

The 'food pipeline' shows the physical and biological ways in which some losses occur. In order to alleviate these losses, it is apparent from the 'pipeline' that quite an extensive work is required, and it needs careful blending of concepts and procedures of several sciences ie people from various disciplines should be involved like - Agricultural economics, Agricultural engineering, Agricultural extension, entomology, food marketing and rural sociology.

III-2. Procedure for loss assessment

The personnel required to carry out programmes of food loss estimation do not all require a high degree of technical skill (see Appendix V). At the planning and supervisory level, however, it is important that responsible persons have a thorough grasp of the complexities of post harvest food processing and distribution, along with sufficient knowledge to call on the various disciplines essential to loss estimation programmes.
In identifying the points at which losses occur, certain boundary conditions must be considered, such as Political, Economic and Social boundaries. What is technologically ideal may be very different from what is practical and feasible with actual social, economic and political environment. A balancing of technical and social sciences is essential in assessing and reducing grain losses.
The 'pipeline' approach weighs individual loss points in relative magnitude. Combined with consideration of social realities with influence amenability to in depth assessment and loss reduction, the pipeline concept serves to

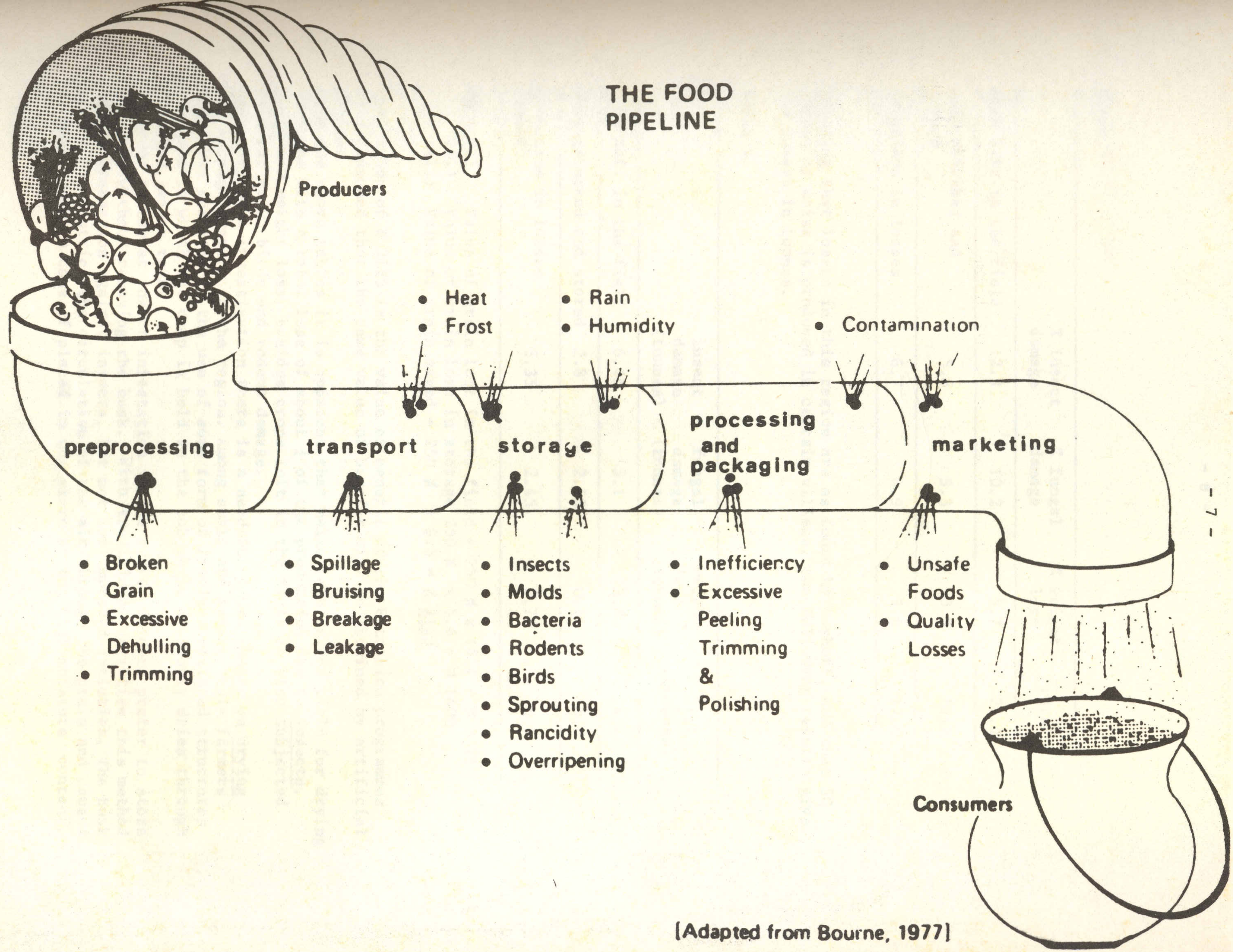
(i) identify critical loss points for indepth assessment
(ii) provide a basis for development of improved technologies for post harvest reduction.

As it can be observed - from Appendix V - detailed post harvest loss assessment is expensive and time consuming. It should be undertaken only if it can ultimately result in a meaningful improvement of the current situation.
Where information on losses is available this can be used to identify main points of loss reduction. Work carried out by Boshoff (1977) on post harvest losses in South West Nigeria, indicated that farmers in this region are faced with a critical timing problem in harvesting and drying of the crop in the brief period between the two seasons (note: there are two rain seasons). In advanced mechanized agricultural systems harvesting and artificial drying are combined. Small scale and medium levels farmers who are dominant producers of maize in the region are the ones faced with a continuing problem in drying and storage of the first season maize crop through various intermediate methods.

III-3. Value of losses in South Western Nigeria

During his investigation, Boshoff, left some maize in the field after maturity for 7 weeks and harvested some and stored in improved cribs for the same period of weeks. The following results were obtained.

Fig. 1.



[Adapted from Bourne, 1977]

Table 1

	% insect damage	% fungal damage	% weight loss	total
crop left in the field	12.3	10.2	5.7	28.2
crop dehusked and stored	5.6	5.3	0.3	11.2
reduction in losses	6.7	4.9	5.4	17.0

Assuming that losses in this region are as found by Boshoff, and that 50 tonnes of maize is produced in certain village, the following results give the losses in tonnes.

Table 2

	insect damage (tonnes)	fungal damage (tonnes)	weight loss (tonnes)	total (tonnes)
crop left in the field	6.15	5.1	2.85	14.1
Crop dehusked and stored	2.8	2.65	0.15	5.6
Reduction in losses (saved)	3.35	2.45	2.70	8.5

NB.: (i) Value of grain lost in the field = 250 ₦ x 14.1 = ₦ 3525
(ii) Value of grain loss in storage 250 ₦ x 5.6 = ₦ 1400
(iii) Value of grain saved = 250 ₦ x 8.5 = ₦ 2125

This value of ₦ 2125 is the value of benefit of the Extension programmes it is assumed that the same value of benefit will be obtained by artificial drying.

From the above tables it is apparent that maize left in the field for drying is faced with a total loss of about ¼ of the production due to insects, mould and weight loss, besides crops left in the field is also subjected to wind, rain, birds and rodent damage.

From the above investigation there is a need for improvements on drying and storage systems in the region. Among small and medium scale farmers some have resorted to the use of some form of freely ventilated structures or store in which the crop is held in the cob while it slowly dries through a second season rain.

In order to combat insect infestation in the store, farmers prefer to store the cobs without removing the husk. With traditional varieties this method offers protection against insects, but not for improved varieties. The husk on the cob restrict the circulation of the air through the grain and causes fungal growth in cobs if placed in the store at too high moisture content.

IV. ALTERNATIVE POSSIBILITIES FOR LOSS REDUCTION

As mentioned earlier the farmers in this region are faced with field and storage losses. There are two alternatives for solving the problems of losses. The first one is an introduction of an Artificial Dryer. The second is an Extension Service Programme which will involve educating farmers on how to improve their storage structures such that maize of higher moisture content can be stored in then.
In consideration of the drying unit, some storage and drying experiments were carried out to determine the maximum number of days that moist grain can be kept without deterioration whilst awaiting drying by artificial means and to determine the capacity of a dryer by studying the relationship between capacity, drying rate, temperature, relative humidity and velocity of drying air. Details of these experiments are given in Appendix II.
For both the Extension Programme and the Artificial Drying Unit, the first year of operation will be devoted to carrying out a campaign to introduce the proposed projects to the farmers, therefore no monetary benefits will be derived.

IV-1. Introduction of Drying Unit

For the drying unit we have chosen IRRI Batch dryer. The reasons for choosing this type of dryer in the region are:

a. The medium sized farm or a group of small scale farmers have the potential to utilize low cost farm drying. Therefore, the development of economical village or farm level drying for use and manufacture in the developing countries is of urgent necessity.
b. Performance of this drier has good features such as;
   - low cost
   - uses engine as supplementary heat source
   - is compact and portable
   - needs little maintenance and easy to operate
   - has automatic safety feature to shut off burner assembly
   - bin design of wood or steel construction.

The region has two planting seasons, one major and one minor season. There are 100 farmers who will bring their maize to the central position where the dryers will be built. Total production in this village is 50 tons, 30 tons are produced in the major season and 20 tons in the minor season. The bulk density of maize are found from drying experiments is 397 kg/m^3. The time required to dry one meter square maize of 30 centimeters thickness (119 kg/m^2) with a drying air temperature of 32°C and 50% relative humidity and air velocity of 0.19 meters per second was found to be 20 hours. Allowing 2 hours for handling total drying time required is 22 hours. (See Appendix III-2). Data used in calculation of drying time was obtained from drying experiments of Pelgröm (1976) because his drying air conditions are similar to what is obtainable in the hot humid South Western Nigeria. Our experimental results on the other hand could not be used because of the difference in the air conditions used and that obtainable in South Western Nigeria.
The drying period of 22 hours can be broken down into 2 days of eleven hours drying per day. Assuming that the harvesting period of maize is 30 days, then maize harvesting ~~period~~ on the last day of this period can keep for approximately 10 days as found from storage experiments.

There is therefore a period of 40 days for the drying of 30 tons of maize in the major season. Since a batch of maize can be dried in 2 days, 30 tons can be dried in 20 batches of 1.5 tons per two days.
To dry 1.5 tons of maize a drying floor of 12.6 m^2 (1.5/0.119 m^2) is required. This can be provided by 3 IRRI batch dryers each with a drying floor of 5.3 m^2. Specifications of the IRRI batch dryer is given in Appendix IV.

IV-2. Extension service programme

IV-2-I. Preamble

Under this programme improvements on the traditional drying and storage systems will be carried out. This work will be carried out in 8 weeks after the harvesting period. The whole programme is expected to last for 5 years, after which the comparison is made with the other alternative i.e. Artificial Dryer in terms of reduction in post harvest losses (monetory terms).

IV-2-II. Village site

The selected is about 20 km away from the provincial headoffice. There are 100 farmers expected to get the extension service and they are small scale farmers. It is estimated that the total production of maize in this particular village is about 50 tonnes out of which 30 is harvested during the major season and 20 tonnes in the minor season.
As already indicated, ~~before~~, the work is expected to last 8 weeks after harvesting period and 6 working days for every week. One crib must be replaced after every 2 years, at a cost of ₦ 7.7 per crib (Fig. 3).

IV-2-III. Personnel

The personnel to be involved in this programme will be:

a. Extension officer. He will be a post-secondary graduate and will teach the farmers on the improvements of the already existing drying and storage systems and demonstrations on the application of pesticides e.g. Malathion. This will be a full time job.
b. Socialogist. He will be a graduate, whose work will be to find out how much the innovation fits with the traditional storage and drying systems. This work will be conducted approximately for a period of weeks.
c. Economist. The qualification of the Economist, he will be a University graduate and his work will be to cost the whole programme.
d. Driver. His work will continuous i.e. 48 days.
e. Labourers. Three labourers will be required to build one crib per day.

IV-2-IV. Equipment and transport

a. Portable black-board.
b. Pesticides.
c. Stationery
d. Toyota.
e. Gunny bags.
f. Building.

V. ECONOMIC ANALYSIS OF ALTERNATIVES

In this section the costs of operating the dryer and extension service are compared against the value of grain to be saved by any of these alternatives using benefit-cost ratio (B/C).
The amount of grain to be saved is 8.5 tonnes which is worth ₦ 2125 per annum, and this amount is the profit for the project. The B/C for each alternative is obtained by dividing the total discounted benefits by total discounted costs for a period of 5 years using discount factor (D.F.) of 12%).
When the ratio is less than 1, the project is not recovering its investment costs, and if it is more than one, it is recovering its investment costs, hence the project is worth undertaking.
The ratios for the two projects are compared. The B/C ratio is valuable in comparing the two alternatives because the benefits are the same. The analysis were extended for another period of 5 years and the results are compared as above.
Tables 3 and 4 give the cost breakdown for the drying unit and extension programme respectively the benefit cost analysis are given in tables 5 and 6.

Table 3: Cost break-down for drying unit.

Year	Investments cost (₦)		Cost production (₦)	
1	1. Building	1,800	4. Labour	
	2. Dryers (1)	600	- 1 skilled } for construction	5
	3. Moisture Tester (1)	30	- 2 unskilled } of dryer	3
			5. Salaries (20 days)	
			- extension officer (1)	100
			- technician (1)	100
			- labourers (2)	50
			6. Fuel	
			- kerosene	83
			- gasoline	50
			- lubricant	2
			7. Gunny bags	70
			8. Maintenance of drier	50
			9. Contingensies 10%	51
	Total	2,430		564
2	1. Dryers (2)	1,200	3. Labour	
	2. Moist.tester (1)	30	- 1 skilled } for construction	10
			- 2 unskilled } of dryers	5
			4. Salaries	
			- 2 technicians	670
			- 3 unskilled labourers	167

		5. <u>Fuel</u>	
		- kerosene	279
		- gasoline	169
		- lubricant	11
		6. Gunny Bags	350
		7. Maintenance of drier	150
		8. Contingencies 10%	181
Total	1,230		1,992
3	-	1. <u>Salaries</u>	
		- 2 technicians	670
		- 3 unskilled	167
		2. <u>Fuel</u>	
		- kerosene	279
		- gasoline	169
		- lubricant	11
		3. Gunny bags	350
		4. Maintenance of drier	150
		5. Contigencies	180
			1976
4	-	same	1976
5	-	same	1976

Table 4: Cost analysis of drying unit.

Year	Investment (₦)	Production cost (₦)	Total cost (₦)	Gross Benefit (₦)	Discount Factor at 12%	Present worth cost (₦)	Present worth benefit (₦)	
1	2,430	564	2,994	-	0.89	2,665	0	
2	1,230	1,976	3,206	2,125	0.79	2,533	1,679	BC ratio= 0.64
3	-	1,976	1,976	2,125	0.71	1,403	1,509	(5 years)
4	-	1,976	1,976	2,125	0.64	1,265	1,360	
5	-	1,976	1,976	2,125	0.57	1,126	1,211	
					Total	8,992	5,759	
6	600	1,976	2,576	2,125	0.51	1,314	4,335 (years 6–10)	
7	1,200	"	3,176	"	0.45	1,429		
8	-	"	1,976	"	0.40	2,134 (years 8–10)		
9	-	"	"	"	0.36			
10	-	"	"	"	0.32			
					Subtotal	4,877	4,335	
					Overall total	13,869	10,094	BC ratio= 0.73 (for 10 years)

Notes Drying Unit

In the first year only 5 ton maize will be dried, and 50 tons each in the subsequent years.

The first year

1. 1 building and land $60m^2$ at ₦ $30/m^2$
2. 1 IRRI batch dryer at ₦ 600.-
3. 1 moisture tester (cera type) at ₦ 5.-
4. Labour for a day
   - 1 skilled at ₦ 5/day
   - 2 unskilled at ₦ 1.25/day
5. Salaries for 20 days
   - 1 extension officer at ₦ 5/day
   - 1 skilled at ₦ 5/day
   - 2 unskilled at ₦ 1.25
6. Fuel consumption
   - gasoline 3630 litres (1.5 l/hr) at 15.3 K/litre
   - kerosene 594 litres (2.7 l/hr) at 14.0 K/litre
   - lubricant 8.8 litres (0.04 l/hr) at 38 K/litre
7. Gunny bags 10 at ₦ 7/day
8. Maintenance of dryer 12%/year.

The second year

1. 2 dryers at ₦ 600.-
2. 1 moisture tester (cera tester) at ₦ 30.-
3. Labours for 2 days
   - 1 skilled for construction 2 drier ₦ 5/day
   - 2 unskilled for construction 2 drier ₦ 1.25/day
4. Salaries for 67 days
   - 2 technicians at ₦ 5/day
   - 3 unskilled at ₦ 1.25/day
5. Fuel consumption
   - kerosene 1990 litres (2.7 l/hr) at 14 K/litre

- gasoline 1106 litres (1.5 l/hr)
  at 15.3 K/litre
- lubricant 30 litres (0.04 l/hr)
  at 38 K/litre

6. Gunny bags 50 at ₦ 7/day
7. Maintenance of drier 12%/year.

For the third, fourth and fifth the same calculation is done.

Table 5 Cost Breakdown of extension service

Year	Fixed investments	Annual Operation costs (₦)	(₦)
I	1. 10 cribs 77 ₦	1. 3 labourers a) 1.25 ₦/crib	37.5
	2. single office 750 ₦	2. Salaries 1. extension officer	600
	3. 1 toyota 7,000 ₦	2. sociologist	700
	4. 1 blackboard 30 ₦	3. economist	700
		4. driver	480
		3. Pesticides	20
		4. Gunny bags 50 a 0.7 ₦	35
		5. Petrol 2 ₦/day x 48 x 2	192
		6. Maintenance	1,000
		7. Stationaries	90
		8. Sub-total	3,154.5
		9. Contigencies (10% total cost)	315.45
TOTAL	7,857	TOTAL	3,469.95
II	100 cribs a) 7.7.= 770	1. Labour	375
		2. Salaries	2,480
		3. Pesticides	400
		4. Gunny bags (500 bags) a 0.7 0.7 ₦	350
		5. Petrol	192
		6. Maintenance	1,000
		7. Stationaries	90
		Sub-total	4,887
		8. Contigencies 10%	488.7
TOTAL	770	TOTAL	5,375.7

Year	Fixed investments		Annual Operation costs (₦)	(₦)
III			1. Salaries (4 people)	2,480
			2. Pesticides	400
			3. Gunny bags	350
			4. Petrol	192
			5. Maintenance	1,000
			6. Stationaries	90
			7. Sub-total	4,512
			8. Contigencies	451.2
			9. TOTAL	4,963.2
IV	100 cribs	770	SEE YEAR II	
TOTAL		770	TOTAL	5,375.7
V			SEE YEAR III	
			TOTAL	4,963.2

Table 6: Cost analysis of extension service to improve storage structures

Year	Investment (₦)	Production Cost (₦)	Total Cost (₦)	Gross Benefit (₦)	Discount Factor at 12%	Present worth cost (₦)	Present worth Benefit (₦)	
1	7,857	3,470	11,327	-	0.89	10,081	0	
2	770	5,376	6,146	2,125	0.79	4,855	1,679	BC ratio= 0.23
3	-	4,963	4,963	2,125	0.71	3,524	1,509	(for 5 years)
4	770	5,376	6,146	2,125	0.64	3,933	1,360	
5	-	4,963	4,963	2,125	0.57	2,829	1,211	
					Total	25,222	5,759	
6	770	1,125	1,895	2,125	0.51	967	1,084	
7	-	750	750	2,125	0.45	338	956	
8	770	1,125	1,895	2,125	0.40	758	850	
9	-	750	750	2,125	0.36	270	765	
10	770	1,895	1,895	2,125	0.32	606	680	
					Sub Total	2,939	4,335	
					Overall Total	18,161	10,094	BC ratio= 0.56 (for 10 years)

Notes Extension Services

1. Cribs Cribs will be built from locally available materials like:
   - bamboo reeds
   - grass for thatching life span of which is 2 years
   - wooden poles
   - rat guards

   Costs The cost of building material is 7.7. ₦

2. Petrol Charges is 0.05 ₦/km

3. Labour The cost of labour for unskilled labourers is 1.25 ₦/day

4. Building (Office/store)

   Cost of building is at rate of ₦ 30/m^2, the office/store will occupy m^2

5. Salaries

   1. graduate salary 350 ₦/month
   2. post-secondary graduate 150 ₦/month

6. Stationaries

   Each personnel i.e.

   1. Extension officer
   2. Sociologist will need 150 ₦ per year
   3. Economist

VI. COMPARISON OF DRYING UNIT AND EXTENSION SERVICE

From tables 4 and 6 it is apparent that both projects are not recovering the total investment since the B/C ratios are less than one for the first period 5 years. Although both projects are not paying in the first 5 years, drying unit with B/C of 0.64 is slightly better compared to the extension service with B/C ratio of 0.23. The extension service requires a lot of costs particularly salaries of the skilled personnel and transport costs whilst the drying unit does not require high skilled personnel and transport in operating the unit.
For a second period of 5 years the picture becomes better. Over those 5 years benefits are larger than costs in the case of the extension programme. In the case of the drying, costs are still higher because new dryers should be installed in years 6 and 7. However, the overall project costs over the 10 years will not be covered in both cases.

VII. CONCLUSIONS AND RECOMMENDATION

Non of the two alternatives are cost covering over a period of 5 years as well as 10 years. However, the extension project has large initial costs but for the farmers the project is profitable as can be seen from Table 6. Benefits are 1.5 times higher than costs when looking from year 6 onwards. Therefore the extension project can be considered better in the long run compared to the drying unit.
Other factors in the choice of the extension service are:

1. Involves all farmers in the area, by each one building up modern crib in his household, unlike the dryer, where the farmers won't be involved physically in the operation of a dryer.
2. Builds up local skills and technology on drying and storage systems, whilst for the drying unit it is completely an innovation.
3. Depends entirely on locally available building materials, unlike for a dryer in which some components must be imported, like the motor.

In addition to the above, drying unit has more of the following shortfalls:
(i) It takes longer time to dry a small amount of grain.
(ii) For small scale farmers it is uneconomical.
(iii) Farmers may not be willing to mix their grain.
In such a feasibility study a social economic survey is very relevant as this can bring out factors such as farmers willingness to work on co-operative basis or not. From the sensitivity analysis (Appendix VII) when price of maize was increased by 10%, the B/C ratio's of both projects were higher. For five as well as ten years however both projects were still not recovering as shown by B/C ratios of less than one. In view of the above conclusion, the team recommends that the extension service should be introduced in solving the problems of losses in the area. However, if the dryer could be used for other purposes during the off-season the picture could possibly change.

APPENDIX I - TABLE 1 SUMMARY OF DRYING AND STORAGE SYSTEMS FOR MAIZE

(in Ghana, Indonesia, Tanzania and Zambia)

Type of structure/country	Use	Advantages	Disadvantages
1. Cribs			
1.1. Dungu, Butala -(fig.1) - Tanzania, Zambia and Indonesia	Drying/ storage	1) Rat guards can be fitted 2) Well ventilated 3) Easy to clean and inspect	(1) Highly susceptible to insect attack, because unhusked maize offers micro-environment for insect growth
1.2. Ewe barn-Ghana Fig. 2	Drying/ storage	1) Well ventilated 2) Rain water can easily be drained	(1) Highly susceptible to rat attack (2) Husks provides micro environment for insect breeding
1.3. Sun-Air drying Platform - Chanja-Tanzania Chisanza-Zambia Fig. 3	Drying	1) Easy to inspect and clean 2) Insecticide dust can be applied 3) Well ventilated 4) Rat guards can be attached	(1) Risk from rain if not supplied with a roof (2) Drying is not fast
1.4. Ashanti Crib (fig. 4) - Ghana	Drying/ Storage	1) Well ventilated 2) Easily inspected 3) Rat guards can be attached	(1) Absorb moisture if not rained from the ground (2) Drying not fast if too wide
2.0. Cross-bar - Indonesia - Ghana - Tanzania - Zambia	Drying/ storage	Easy to construct	Exposed to rain and insect

Type of structure/country	Use	Advantages	Disadvantages
3.0. Granaries (Fig.s: 5-8) - Ghana - Tanzania	Storage	1) Effective against insect and rat attack if air tight 2) Easily fumigated	(1) Can not be cleaned easily or inspected (2) Mould growth if produce not properly dry (3) Sprouting may occur if grain not properly dried
4.0. Sealing or Roof Dryer (Fig. 9) - Tanzania - Ghana, Zambia, Indonesia	Drying/ storage	1) Efficient in drying 2) Inexpensive	(1) Vulnerable to rat attack (2) Inaccesible during cleaning and inspection (3) Insecticide cannot be dusted freely (4) Unhusked maize provide micro-environment for insect growth
5.0. Kilindo (Fig. 10) - Tanzania	Storage	1) Effective against insect and rat attack	- Because it is semi airtight mould can easily form if moisture content of grain is not safe
6.0. Claypots (Fig. 11) - Zambia, Ghana - Indonesia, Tanzania	Storage (seeds)	- Effective against rats	- As above
7.0. Gourds (Fig. 12)	Storage (seeds)	- Easy to fumigate	- Vulnerable to termite and rats

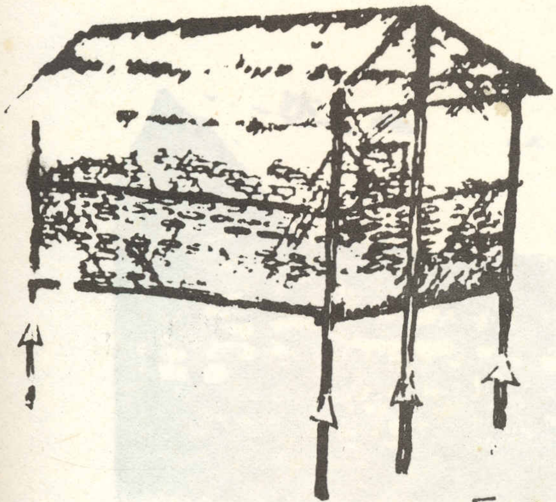


FIG. I DUNGU (IMPROVED)

FIG. 2 EWE BARN (GHANA)

FIG. 3 CHANJA - TANZANIA

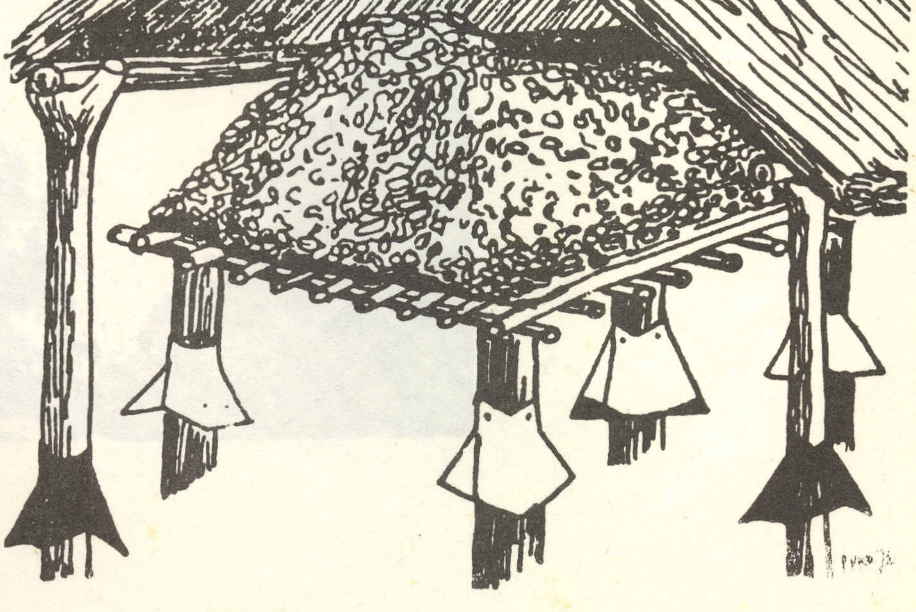


FIG. 4 ASHANTI CRIB (GHANA)

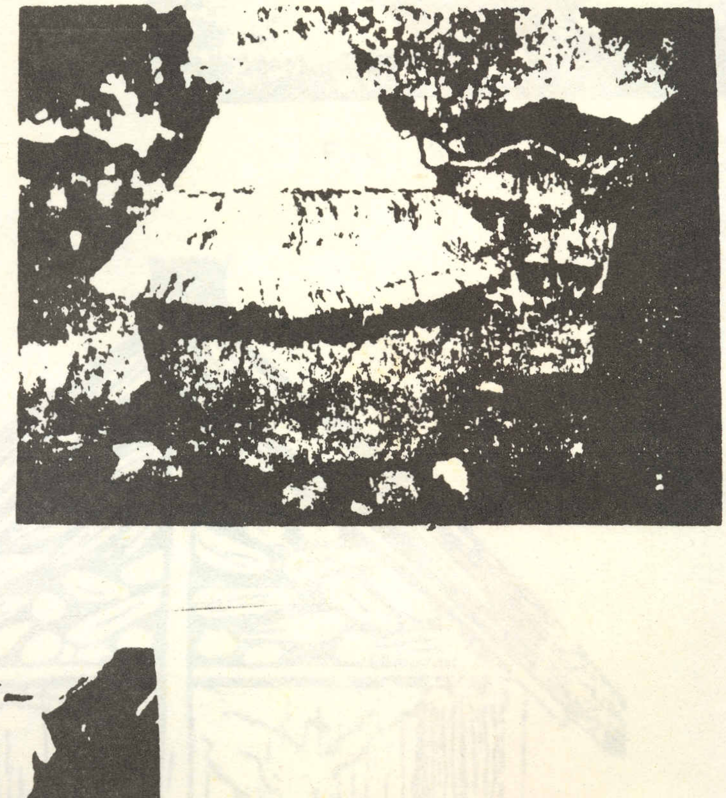


FIG 5

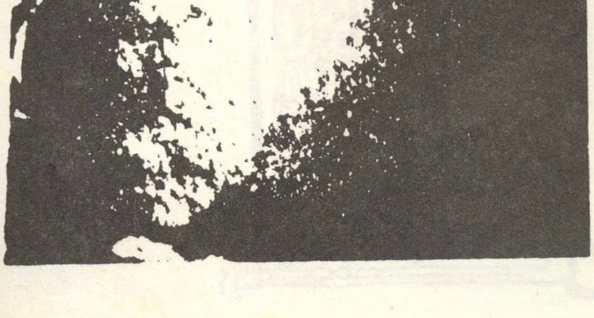
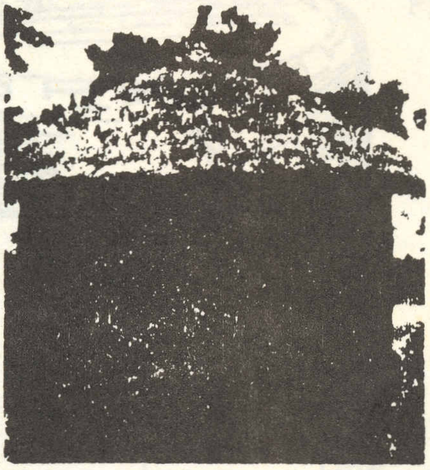


FIG 6

Fig. 7



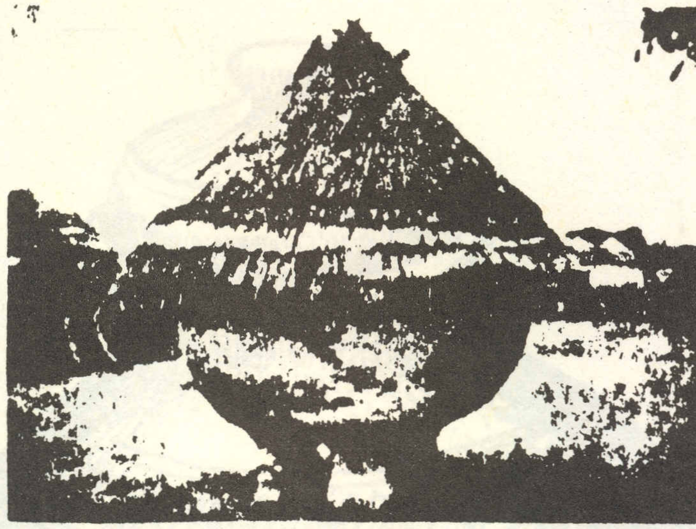
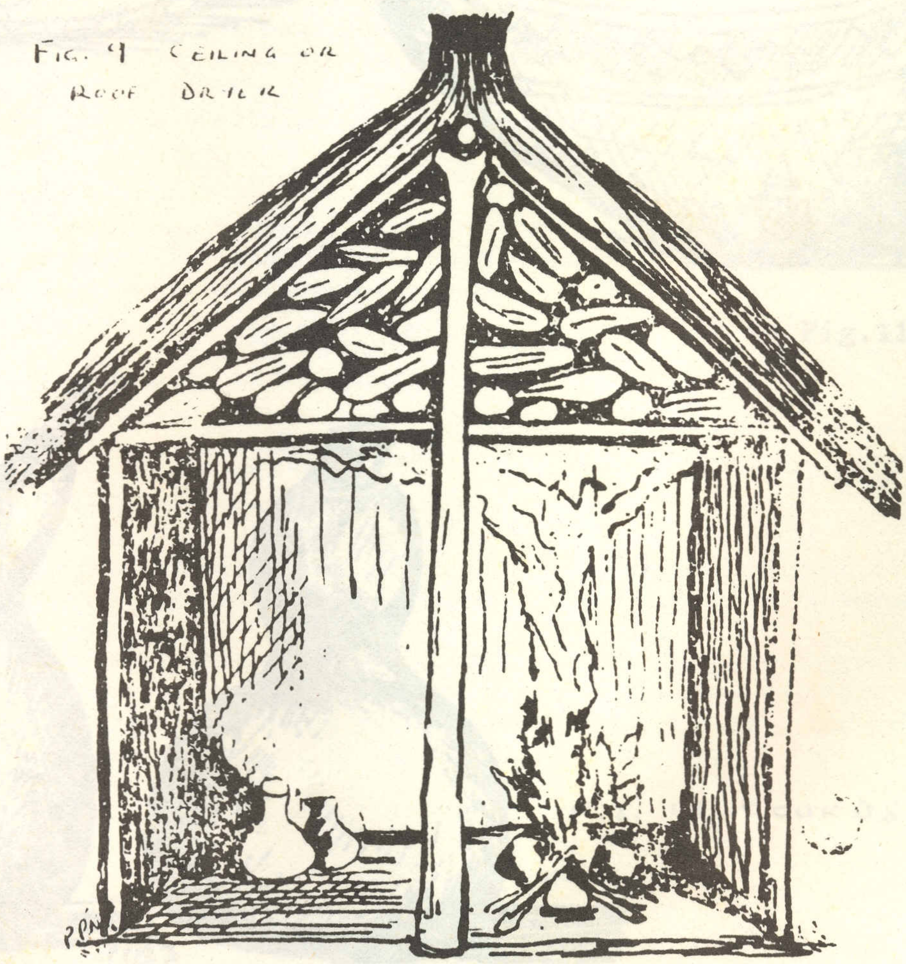


Fig. 8

Fig. 9 Ceiling or Roof Drier



KILINDO

Fig.10 (Tanzania)

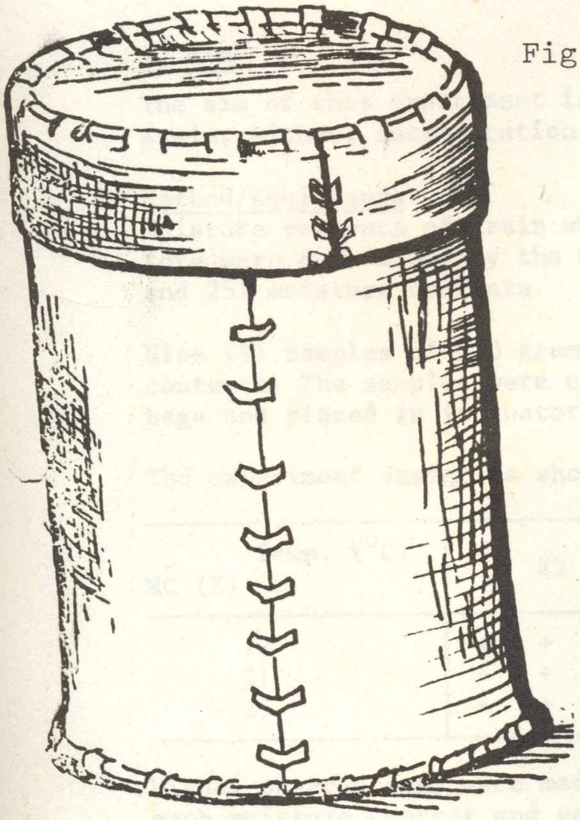


Fig.11 Clay Pot.

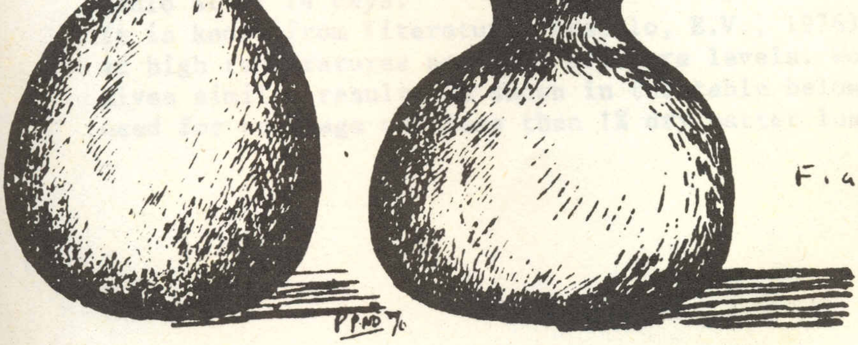


Fig. 12 GOURDS

APPENDIX II - STORAGE EXPERIMENT

1. Aim

The aim of this experiment is to determine the maximum storage period of wet grain, without deterioration while waiting to be dried.

Method/Equipments

Moisture contents of grain which has been conditioned (moistured) a week before were determined by the use of moisture meter and these were 17%, 21% and 25% moisture contents.

Nine (9) samples of 500 grams each were taken from respective grain moisture contents. The samples were completely sealed in the two layers polyethylene bags and placed in incubators at existing temperatures in the tropics.

The experiment design is shown below:

Temp. (^{o}C) / MC (%)	25			30			37		
17	+	+	+	+	+	+	+	+	+
21	+	+	+	+	+	+	+	+	+
25	+	+	+	+	+	+	+	+	+

Visual observations were made after 3, 7, 10 and 14 days. One sample from each moisture content and each temperature was taken out of the incubator for examination. The criterion used for determining spoilage was mould cover. The observations were carried out for 2½ weeks.

2. Results and discussion

Table 2: Safe storage period in days with criterion mould cover 5-10% of the container

Temp. ^{o}C / MC %	25	30	37
17 %	>14	>14	>14
21 %	7 <10	7 - 10	7 <14
25 %	< 7	< 7	< 7

It is clear from the table that grain with higher moisture content and high temperature deteriorated faster (7 days). All the grain was covered with mould after 14 days.
It is known from literature (Araullo, E.V., 1976) that mould growth is rapid at high temperatures and high moisture levels. Work done by Brooker 1974, gives similar results as shown in the table below; however, the criterion used for spoilage was less than 1% dry matter loss.

MC / Temp. °C	15	20	25	30
24	116	12	4	2
21	155	16	5	3
18	207	21	7	4
15	254	27	9	5

Source: Brooker 1974.

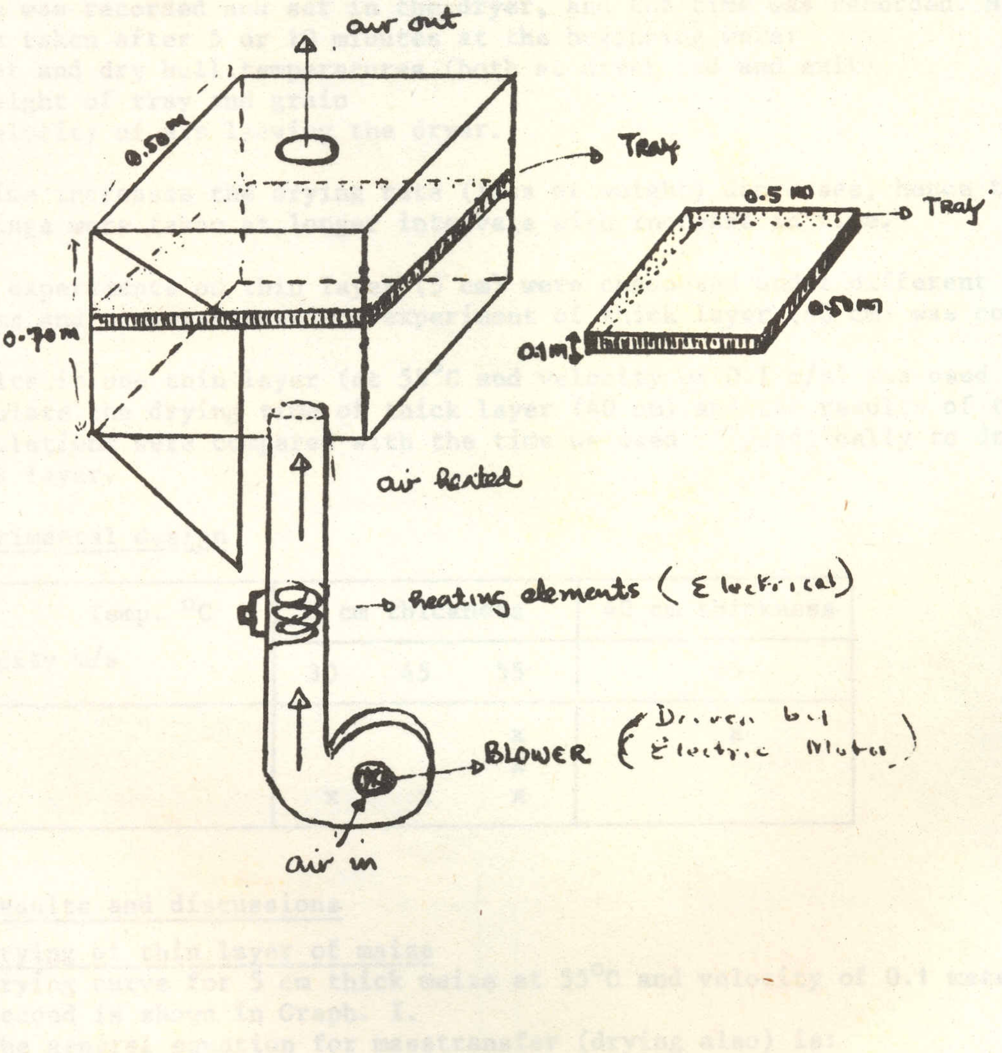
APPENDIX III-1 - DRYING EXPERIMENTS

1. Aims

a. To collect data from drying experiments with thin layer of maize.
b. To use data from the thin layer to determine the drying time for a thick layer of maize.
c. To determine the capacity of a dryer needed in a drying unit by the use of data obtained in (b).

2. Method/Equipment

Fig. 1 Cabinet Tray Dryer



The method used in drying is by convection. Heat is transported to the layer of maize to supply the energy of vaporization of water, thus reducing the moisture level of grain to safe moisture level. The type of dryer we used to carry out experiments was 'Cabinet Tray Dryer' (Fig. 1), in which several trays can be put in above each other, the thickness of the layer can therefore be varied up to 0.5 m.

Before the drying procedures started, the following parameters were measured in relation to the dryer.

a. Velocity of the air leaving the dryer at the exit from which the velocity of the drying air through the grain layer was calculated.
b. Temperature of drying air.

After the measurements of the above mentioned parameters were conducted, maize of 5 cm thickness with 25% M.C. (thin layer) or 40 cm thickness (thick layer) was put in a tray of known weight. The weight of tray and maize was recorded and set in the dryer, and the time was recorded. Measurements taken after 5 or 10 minutes at the beginning were:

a. Wet and dry bull temperatures (both at dryer bed and exit)
b. Weight of tray and grain
c. Velocity of air leaving the dryer.

As time increases the drying rate (loss of weight) decreases, hence the readings were taken at longer intervals with increase in time.

Five experiments on thin layer (5 cm) were conducted under different velocities and temperatures. One experiment of thick layer (40 cm) was conducted.
Results in one thin layer (at 55°C and velocity of 0.1 m/s) was used to calculate the drying time of thick layer (40 cm) and the results of these calculations were compared with the time we used practically to dry a thick layer.

Experimental design

Temp. °C / Velocity m/s	5 cm thickness			40 cm thickness
	30	45	55	55
0.10			x	x
0.25			x	
0.50	x	x	x	

3. Results and discussions

A. Drying of thin layer of maize

Drying curve for 5 cm thick maize at 55°C and velocity of 0.1 meter per second is shown in Graph. I.
The general equation for masstransfer (drying also) is:

$$\frac{dm}{dt} = k\ (\bar{M} - M_e) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (1)$$

for set of boundary conditions we can solute equation (1)

$$\frac{\bar{M} - M_e}{M_o - M_e} = MR = e^{-kt} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

Boundary conditions being $t \longrightarrow 0 \qquad \bar{M} = M_o$

$t \longrightarrow \infty \qquad \bar{M} = M_e$

Where $\bar{M}$ = average moisture content in the grain
M_e = equilibrium moisture content when grain is in equilibrium with drying air
M_o = initial moisture content of grain.

Therefore Ln MR against time is a straight line see graph. II of LN MR/ time for 5 cm/55^{o}C/0.1 m/s.
From graph $t_{\frac{1}{2}}$ can be obtained.

$t_{\frac{1}{2}}$ is time required to dry a thin layer of maize from MR= 1 to MR= 0.5.

Tables 1 and 2 shows the $t_{\frac{1}{2}}$ values obtained for drying experiments with thin layer of maize.

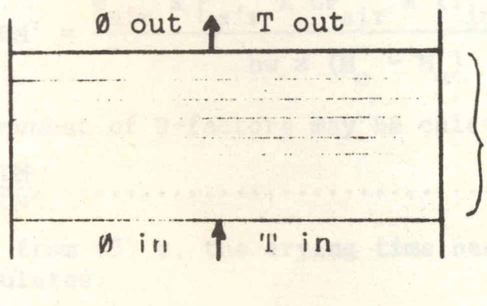
Table 1 - Influence of velocity on drying at 55^{o}C (thin layer 5 cm)

velocity (m/s)	0.5	0.25	0.1
$t_{\frac{1}{2}}$ (min)	61	57	69
R.H. (%)	8.6	9	5

Table 2 - Influence of temperature on drying a thin layer (5 cm) at fixed velocity of 0.5 m/s

Temperature (^{o}C)	30	45	55
$t_{\frac{1}{2}}$ (min)	132	79	61
R.H. (%)	22	10	9

B. <u>Drying a thick layer of maize</u>



Thick layer of grain

Assuming there are no heat losses then only heat of air is used for evaporation.

∴ Heat balance over the system:

Amount of heat required to evaporate x kg of water from maize = heat content of the air used to evaporate this water.

This means:

$hw \times DM \times (M_o - M_e) =$

$\emptyset_{air} \times \rho_{air} \times CP_{air} \times (T_{in} - T_{out}) \times t$ .... (3)

Where
- hw = heat required to evaporate 1 kg of water from maize
- DM = kg dry matter in the bed
- t = drying time
- M_o = initial moisture content of grain
- M_e = equilibrium moisture content when grain is in equilibrium with drying air.

It can be obtained from Sorption isotherm of maize or obtained by calculation from the equation:

$$M_e = \left[\frac{\text{Ln } 1 - R.H}{(6.87\times10^{-5})\ (T_{air}^{(^oC)} + 45.556)} \right]^{0.5}$$

- $\emptyset_{air}$ = flow rate (m^3/hr) = velocity x area
- ρ_{air} = density of air (kg/m^3)
- CP_{air} = specific heat of air (KJ/kg^oC)
- T_{in} = inlet temperature (^oC)
- T_{out} = outlet air temperature (^oC).

According to Hukill (1974) the drying process of a thick layer as function of the drying time and thickness of the layer may be described as follows:

$$MR = \frac{2^D}{2^D + 2^Y - 1} \qquad (4)$$

With
- $Y = t/t_{½}$ .... (5)
- t = drying time for thick layer
- $t_{½}$ = $t_{½}$ for thin layer under same drying conditions
- D = thick factor, gives the amount of dry matter DM' that may be calculated from the heat balance when the drying time is put at $t_{½}$.

$$\therefore DM' = \frac{\emptyset_{air} \times \rho_{air} \times CP_{air} \times (T_{in} - T_{out})\ t_{½}}{hw \times (M_o - M_e)} \qquad (6)$$

and number of D-factors may be calculated from:

$$D = \frac{DM}{DM'} \qquad (7)$$

then from (5) t, the drying time needed to dry a thick layer, can be calculated.

The above theory will be illustrated by using the data obtained from thin layer of 5 cm, dried at 55°C with velocity of 0.1 m/s to calculate time it takes to dry a thick layer of 40 cm thickness under the same temperature and velocity.

$$DM' = \frac{\emptyset_{air} \times \rho_{air} \times CP_{air} (T_{in} - T_{out}) \times t_{\frac{1}{2}}}{hw \ (M_o - M_e)} =$$

$$= \frac{77.94 \times 1.038 \times 1.132 \times (55-23) \times 1.15}{2500 \times (0.33-0.027)} = 4.45 \text{ kg.}$$

T_{out} we read from the Mollier-diagram.
DM from 40 cm thickness = 29.6 kg

$$\therefore D = \frac{DM}{DM'} = \frac{29.6}{4.45} = \underline{6.65}$$

To find the time required to dry grain of 40 cm thickness with indicated dry matter 29.6 kg we can use D-factor.

$$MR = \frac{2^D}{2^D + 2^Y - 1}$$

$$MR = \frac{\bar{M} - M_e}{M_o - M_e} = \frac{2^D}{2^D + 2^Y - 1}$$

$$\frac{0.16 - 0.027}{0.33 - 0,027} = \frac{0.133}{0.303} = 0.4389 = \frac{2^D}{2^D + 2^Y - 1}$$

$$0.4389 = \frac{2^{6.65}}{2^{6.65} + 2^Y - 1}$$

$$2^Y = 129.3879$$

$$Y = \frac{\ln 129.3879}{\ln 2} = 7.012$$

$$Y = t/t_{\frac{1}{2}} = 7.012 = t/1.15 \qquad t = \underline{\underline{8.06}} \text{ hrs}$$

This time is only true if all the heat delivered was used in evaporating water from grain, the assumption made in this case is the efficiency of a dryer being 100%. THis was not true in our experiment since, some heat was lost to the environment by conduction and some heat was also lost during weight measurements since the tray was taken out of the dryer. To know how much heat was used to evaporate water from maize the efficiency of the dryer must be calculated.

Calculation of heat losses:

Thick layer Experiment

A. Heat delivered

$\phi_{air} \times {}_{air} \times C_{Pair} \times (\bar{T}_{in} - \bar{T}_{out}) \times t$

where $\bar{T}_{in} = 55^oC$, $\bar{T}_{out} = 25^oC$, Time = 12 hrs

= 77.9 x 1.038 x 1.132 x 30 x 12 = 32952.15 KJ

B. Heat used for evaporating water = kg H_2O x hw

= 6.7 x 2500 = 16750 KJ

Heat efficiency = B/A = $\frac{16750}{32952}$ = 0.5 or 50%

Energy used to heat up maize

T_{in} maize = 4^oC

T_{end} maize = 39^oC

MC (final) = 12.1

C_p maize = (1.424 + 0.0356) x 12.1

= 1.85 KJ/kg/^oC.

.˙. Energy used to raise the temperature of maize from 4^oC to 39^oC.

= 29.6 x 1.85 x 35 = 1916.6 KJ

Heat used to raise maize temperature = $\frac{1916.6}{32952.15}$ = 5.8%

.˙. 50% of heat delivered to the system was used to evaporate water.
5.8% of heat delivered was used to raise maize temperature.
44.8% of heat delivered was lost to the environment.

$D_{(real)} = \frac{100}{50} \times 6.65$

From this, it can be calculated: t = 15.7 hrs

Discussion on drying a thin layer

From table 1: it is apparent that influence of small velocity is not very much pronounced in a thin layer. This conforms with what is found in the literature (H. Pelgröm, 1976), where the author indicated that there is very little difference in velocities of 0.5 m/s --- 0.8 m/s in drying maize.

From table 2: we can conclude that temperature has got an influence on drying period (time), ie the higher the temperature the shorter the drying time cf 30^oC and in 55^oC. It is also important to note that there is no much difference between 45^oC and 55^oC. In practice higher temperatures are avoided in drying in order to maintain good milling quality of the grain. Maize grain can be dried at a maximum temperature of 60^oC (GATE, 1979), beyond which the grain will break and it will loose its good milling property and viability.

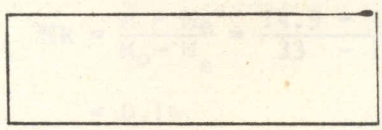
From experiment of 40 cm (thick) layer, time used in drying was 12 hrs, whilst the theoretical time calculated by using the thin layer data was 15.70 hrs, after taking into account heat losses to the environment, and heat required to raise maize temperature.

Source of error

A slight deviation in the linear graph of ln MR against time, will affect the value of $t_{\frac{1}{2}}$ greatly.

APPENDIX III-2 - CALCULATION OF DRYING TIME REQUIRED TO DRY MAIZE IN SOUTH WESTERN NIGERIA USING IRRI BATCH DRYER

For maize of bed thickness of 30 cm and one meter square.



30 cm   Thick layer of grain

1 m

Drying air velocity = 0.25 m/sec
Volume of grain = 0.3 m^3/m^2
Air flow = area x velocity of air = 691.2 $m^3/h/m^2$
Ambient air temperature = 25°C
*Drying air temperature = 32°C
Relative humidity = 50%
Initial moisture content of maize (M_o) = 25% wet matter basis
Final moisture content = 13% wet matter basis
Equilibrium moisture content of maize (M_e) = 12% dry matter basis

$t\frac{1}{2}$ for thin layer drying under similar conditions as given above but air velocity of 0.19 m/sec = 5.5 hours (Pelgrom).
It was found from our drying experiments that the $t\frac{1}{2}$ for a thin layer of grain is not very much affected by change in drying air velocity within a range of 0.1 to 0.5 m/sec. $t\frac{1}{2}$ for a thin layer with air velocity of 0.25 m/sec is therefore assumed to be 5.5 hours.
Using theory of thin layer drying and Hukills (1947) theory on drying process of a thick layer whereby the drying process of a thick layer of grain as function of the drying time of the layer may be described as:

$$MR = \frac{2^D}{2^D + 2^Y - 1}$$

with $Y = t/t\frac{1}{2}$
t = drying time for thick layer
$t\frac{1}{2}$ = $t\frac{1}{2}$ for thin layer
D = thick factor, gives the amount of dry matter DM' that may be calculated from the heat balance when the drying time is put at $t - t\frac{1}{2}$.

$$\therefore DM' = \frac{\emptyset_{air} \times {}_{air} \times C_{pair} \times (T_{in} - T_{out}) t\frac{1}{2}}{hw \times (M_o - M_e)}$$

$$= \frac{691.2 \times 1.038 \times 1.132 \times (32-24)\ 5.5}{2700 \times (0.33 - 0.12)}$$

$$= 63.02$$

DM of 119 kg maize at 25% MC
= 89.25 kg

$$D = \frac{DM}{DM'} = \frac{89.25}{63.02} = 1.4$$

$$MR = \frac{\bar{M} - M_e}{M_o - M_e} = \frac{14.9 - 12}{33 - 12}$$

$$= 0.14$$

From graph of drying time, grain moisture content and grain depth = D ..... Fig. I, Appendix VI.

At D = 1.4 and MR = 0.14
Y = 4

$\therefore t = 4 \times t_{\frac{1}{2}} = 4 \times 5.5 = \underline{\underline{22 \text{ hrs}}}$

From drying experiments with a small quantity of grain the drying efficiency was 50% but we expect a higher efficiency with the IRRI Batch Dryer. With a drying efficiency of about 70 percent then

$$D_{real} = \frac{100 \times 1.4}{70} = 2.0$$

From Fig. I, Appendix VI D of 2.0 and MR = 0.14, Y = 4.5

Drying time = 4.5 x 4.5 = $\underline{\underline{20 \text{ hrs}}}$

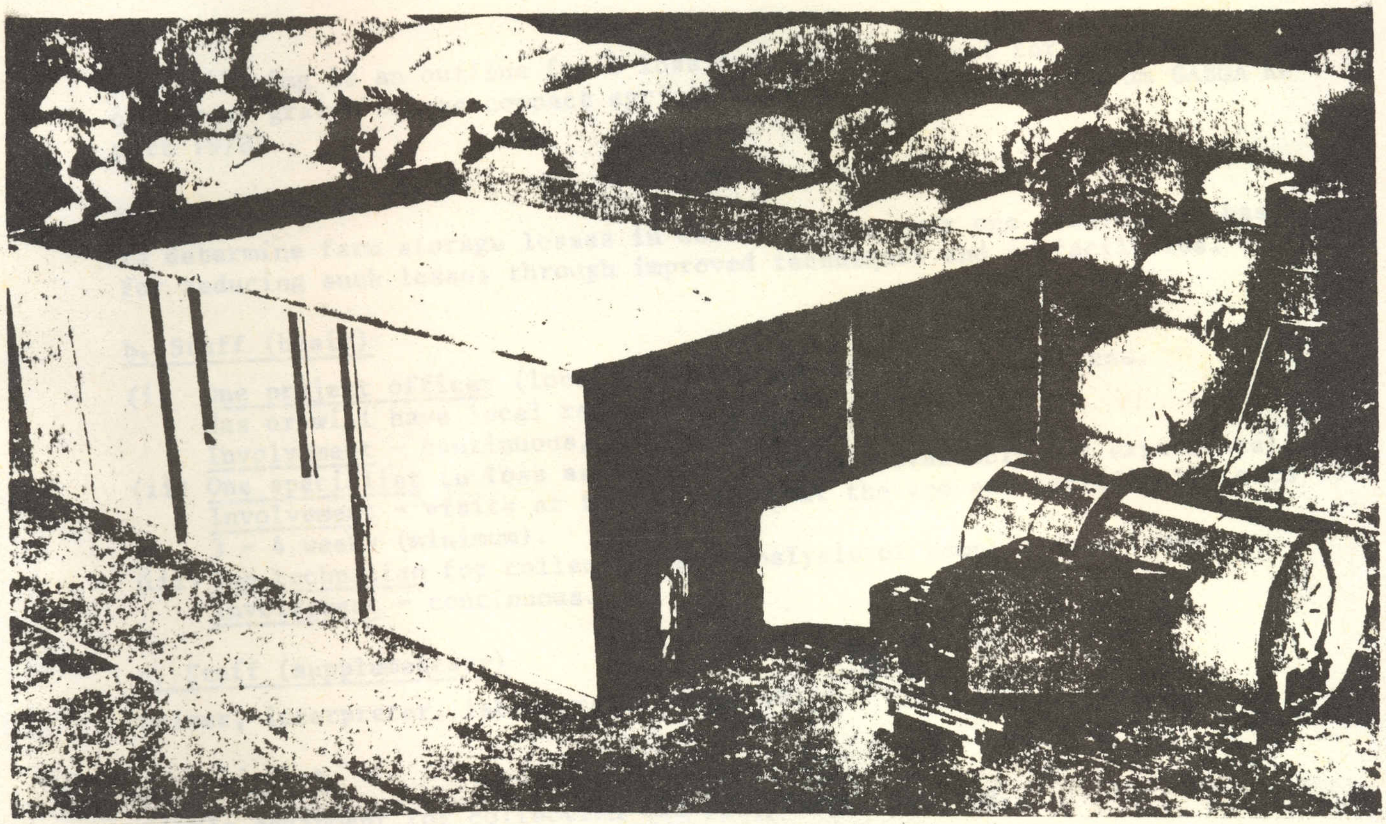
APPENDIX IV - DESCRIPTION OF IRRI BATCH DRYER

This drier has a retangular grain bin with perforated floor, which is connected with a duct to an axial fan and kerosene fired burner to provide heated air at 110 to 130°F (40°C).
The batch type drier consists of the fuel burner, blower and grain bin. The blower drows heated air from the burner or furnace and force it through the grain.
The kerosene burner is a gravity flow pat type which was adapted from an imported design. It consists of bowl, baffle and cover.
A needle value limits the flow of kerosene from a tank. A safety valve which is activated by a conter weighted vane placed in the blower stop.
The blower is an 18 inch diameter vane axial type and is driven by either a 2-JP electric motor or a 3 HP gasoline engine.
The engine can be mounted either on the side or below the blower depending on whether the heat source is kerosene burner or rice hull furnace.

= SPECIFICATION OF IRRI BATCH DRYER =

1.	Power	: 3 HP gasoline engine or 2 HP electric motor.
2.	Length	: 2.8 m bin (5.288 m as a whole)
3.	Width	: 1.9 m bin (2.339 m as a whole)
4.	Height	: 0.80 m (1.213 m as a whole)
5.	Construction	: Wood and steel
6.	Fuel consumption	: Engine 1.5 liter gasoline/hour Burner 2.7 liter kerosene/hour
7.	Blower speed	: 2,000 - 2,200 r.p.m.
8.	Fan	: 56 - 58 cm diameter tube - axial
9.	Drying Air Temperature	: ± 45°C
10.	Air flow	: 1.7 Cu m/sec.

IRRI batch dryer



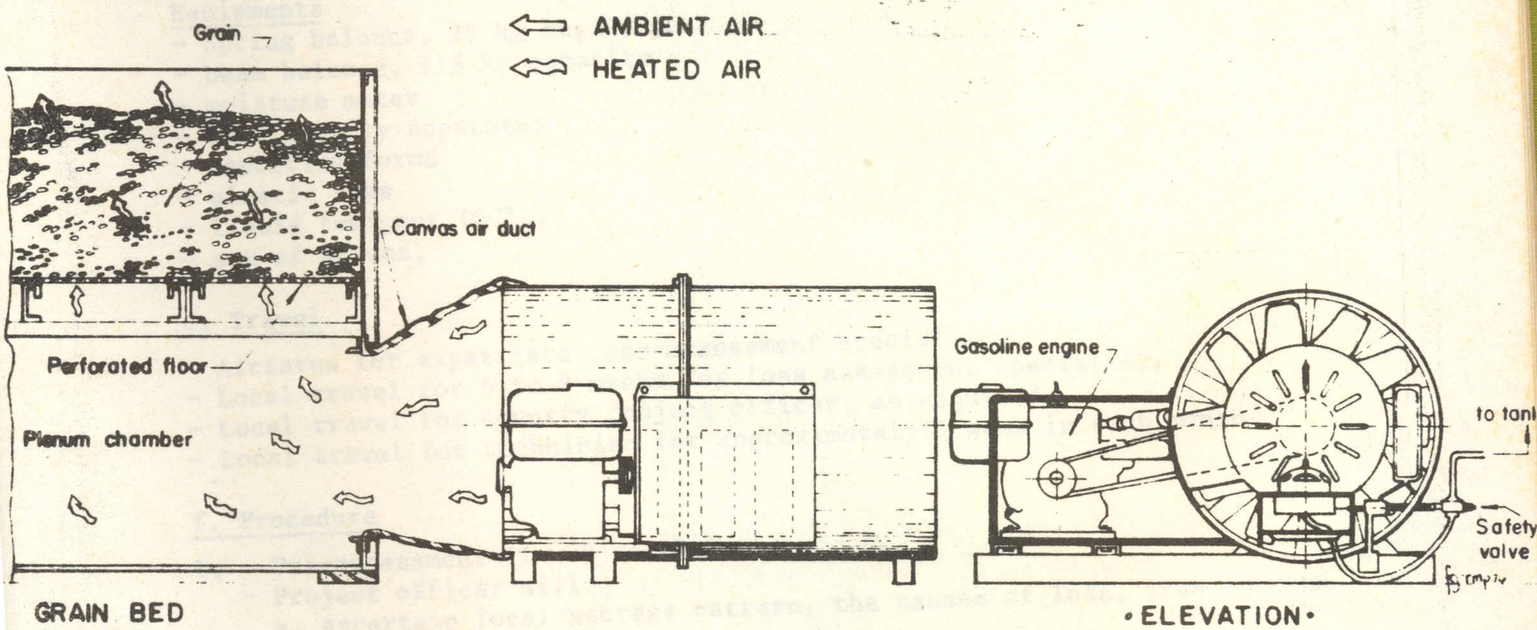


Fig.2 Batch type grain drier

APPENDIX V - PROCEDURE FOR CONDUCTING LOSS ASSESSMENT SURVEY

The following is an outline for a loss assessment project for on-farm storage of cereal grains in one compact agricultural district (Adopted from GASGA Report 1978).

a. Objective

To determine farm storage losses in cereal grains over one season as a basis for reducing such losses through improved techniques and or facilities.

b. Staff (basic)

(i) One project officer (local) with knowledge of farm practices.
Has or will have local responsibility for the project.
Involvement - continuous.

(ii) One specialist in loss assessment (local if available, or expatriate).
Involvement - visits at the beginning at the end and periodically each 3 - 4 weeks (minimum).

(iii) One technician for collection and analysis of samples from farms.
Involvement - continuous.

c. Staff (supplementary)

Driver, interpreter, labourers as required.

d. Equipment

Simple equipment for collection and analysis of samples.

Equipments
- Spring balance, 25 kg capacity
- beam balance, 1.5 kg capacity
- moisture meter
- bulk density apparatus
- reporting forms
- plastic bags
- liquid fumigant (CCl_4)
- set of sieves.

e. Travel

- Airfares for expatriate loss assessment specialist.
- Local travel for 6 to 8 weeks for loss assessment specialist.
- Local travel for country project officer, as required.
- Local travel for technician for approximately 1 week in each month.

f. Procedure

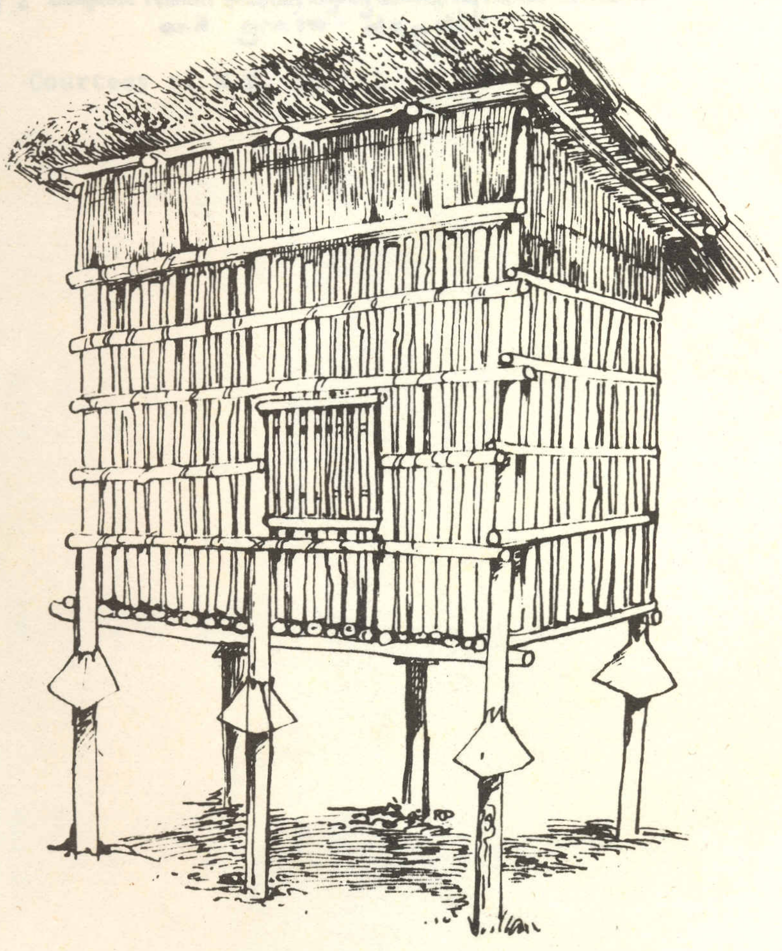
I. Pre-assessment (1 - 3 months)
Project officer will:
a. ascertain local storage pattern, the causes of loss, area for the loss assessment survey;
b. establish contact through correspondence with the loss assessment specialist;
c. personally contact local leaders who are knowledgeable of local farming conditions.

II. Initiating Survey
Specialist will:
a. select farmers immediately prior to harvest;
b. take base line samples and conduct initial analysis (to check the suitability of the loss assessment method).

III. Continuing Survey (whole storage season)
Technician will take monthly samples from all farms:
a. may involve local extension staff for sample collection (under supervision);
b. size of the survey area dependent on the number of farms that can be visited;
c. Contingency plans for bad weather, impassable roads, should be prepared.

IV. Testing improved structures and/or equipment (minimum of whole storage season).
Comparative performance of traditional structures and improved structures may be initiated simultaneously with experimental investigations following usual farm practices. Comparison of losses may be made at or near the end of the farm survey time.

Fig. 3 - A grain crib



APPENDIX VI - Fig. 1

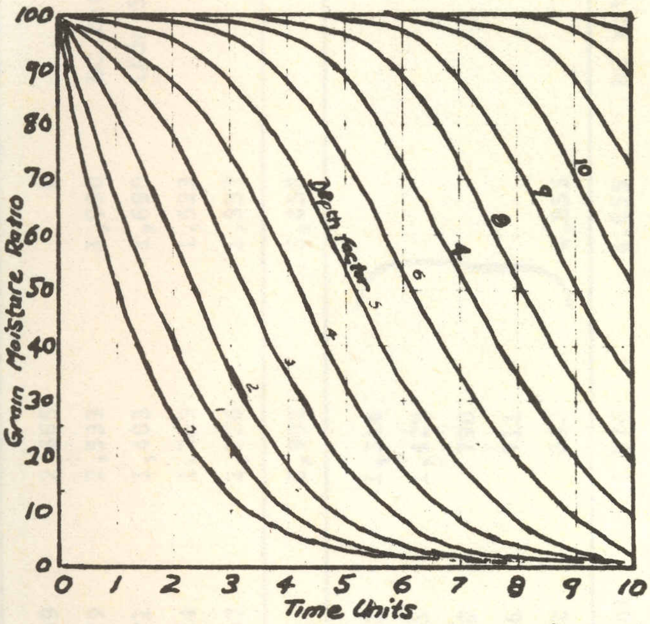


Fig I Computed relation between drying time, grain moisture and grain depth.

Courtesy of W.V. Hukill

APPENDIX VII-1. COST ANALYSIS OF DRYING UNIT
(assuming 10% increase in price, maize from ₦ 0.25 to ₦ 0.30/kg)

Year	Investment Cost (₦)	Production Cost (₦)	Total Cost (₦)	Gross Benefit (₦)	Discount Factor at 12%	Present worth cost (₦)	Present worth Benefit (₦)	
1	2,430	564	2,994	-	0.89	2,665	0	
2	1,230	1,976	3,206	2,380	0.79	2,533	1,880	BC ratio= 0.72
3	-	1,976	1,976	2,380	0.71	1,403	1,690	(for 5 years)
4	-	1,976	1,976	2,380	0.64	1,265	1,523	
5	-	1,976	1,976	2,380	0.57	1,126	1,357	
						8,992	6,450	
6	600	1,976	2,576	2,380	0.51	1,314		
7	1,200	"	3,176	"	0.45	1,429		
8		"	1,976	"	0.40	790		
9		"	1,976	"	0.36	711		
10	-	1,976	1,976	2,380	0.32	632	4,855	
					Sub Total	4,876	4,855	BC ratio= 0.82
					Overall Total	13,868	11,305	(for 10 years)

APPENDIX VII-2. COST ANALYSIS OF EXTENSION SERVICE OF IMPROVED STORAGE STRUCTURES
(assuming 10% increase in price, maize from ₦ 0.25/kg to ₦ 0.30/kg)

Year	Investment Cost (₦)	Production Cost (₦)	Total Cost (₦)	Gross Benefit (₦)	Discount Factor at 12% (₦)	Present worth cost (₦)	Present worth Benefit (₦)	
1	7,857	3,470	11,327	-	0.89	10,081	0	
2	770	5,376	6,146	2,380	0.79	4,855	1,880	BC ratio= 0.26
3	-	4,963	4,963	2,380	0.71	3,524	1,690	(for 5 years)
4	770	5,376	6,146	2,380	0.64	3,933	1,523	
5	-	4,963	4,963	2,380	0.57	2,829	1,357	
					Total	25,222	6,450	
6	770	1,125	1,895	2,380	0.51	966	1,214	
7	-	750	750	2,380	0.45	338	1,071	
8	770	1,125	1,895	2,380	0.40	758	952	
9	-	750	750	2,380	0.36	270	857	
10	770	1,125	1,895	2,380	0.32	606	762	
					Sub Total	2,938	4,856	
					Overall Total	28,060	11,306	BC ratio= 0.40 (for 10 years)

REFERENCES

1. Araullo, E.V., D.B. De Padua and Michaell Graham. Rice Post Harvest
(1976) Technology, IDRC.

2. Boshoff, W.A. Report on work carried out in Nigeria to June 1975.
(1975) FAO/African Rural Storage Centre. Ibadan, Nigeria.

3. Brooker, D.B. et al. Drying cereal grains. Westport Connecticut
(1974) AVI Publishing Company Inc.

4. GASGA , Priorities for Action in Grain Post-Harvest Loss Reduction.
(1978)

5. Hukill, W.V. Basic Principles in Drying Corn and Grain Sorghum.
Agricultural Engineering Vol.28, No. 8

6. Oyenuga, V.A. Agriculture in Nigeria, FAO, Rome
(1967)

7. Pelgröm, H. Het drogen van mais. Koninklijk Instituut voor de Tropen.
(1976)

8. Walden , Crops of East Africa.
(1966)