منظمة الأغذية والزراعة للأمم المتحدة
联合国粮食及农业组织
FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
ORGANISATION DES NATIONS UNIES POUR L'ALIMENTATION ET L'AGRICULTURE
ORGANIZACION DE LAS NACIONES UNIDAS PARA LA AGRICULTURA Y LA ALIMENTACION

FII:FTA/85/33
November 1984

FAO EXPERT CONSULTATION ON FISH TECHNOLOGY IN AFRICA

Lusaka, Zambia, 21-25 January 1985

FII: FIH/85/36

TESTING A SOLAR DOME FISH DRYER IN THE GAMBIA

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ABSTRACT

Heavy losses of traditional cured fish are incurred in the Gambia due to insect attack during drying and storage. In an attempt to improve processing and reduce blowfly infestation, a one-tonne prototype solar dome dryer was constructed and tested at Brufut, one of the major coastal artisanal fish landing and processing sites. Several drying trials were carried out using five different species with the intention of preparing products suited to the local market. The performance of the dryer was compared with sun drying on traditional, flat chicken wire and sloping chicken wire racks. The solar dome did not perform as well as expected from the results of trials on similar designs elsewhere. Very similar drying rates were obtained for sun and solar drying. The poor performance was attributed to the nature of the raw material (ie fermented fish) used to prepare guedja, the local dried product, and the weather. In addition, blowfly infestation was a problem if sufficient care was not taken to prevent the entry of flies into the dryer. Low initial temperatures had to be used in the dome to avoid cooking the fragile raw material so that improved drying rates could not be achieved. These temperatures were too low to kill either the adult blowflies which gained access to the dryer or any larvae that hatched from eggs laid on the drying fish. The dull, wet weather made it difficult to attain and maintain higher temperatures when these were required during the later stages of drying.

INTRODUCTION

The artisanal marine sector is the most productive fishery in The Gambia. In 1981, over 12,000 tonnes of fish were landed by artisanal fishermen, 11,000 tonnes of this by the marine sector. In comparison, the industrial fleet landed 7,600 tonnes during the same year (Drammeh, 1981). Most of the artisanal catch is cured and traditional processing is practised at the major sites.

About 35% of the marine artisanal catch is the pelagic fish, bonga *(Ethmalosa fimbriata)*. Most of this is smoked or sold fresh. Locally, dried fish is called guedja. It is a fermented product and is usually salted. Many species are used to prepare guedja, particularly catfish. Bonga or mullet may be used to produce a fermented guedja product known locally as tambajang. Sharks and rays are also fermented and dried as are sea snails (yete); the latter are never salted. White fish (cassava fish, ladyfish, barracuda, grouper and sole) are usually sold fresh although some may be cured.

During a survey of the losses incurred in traditionally cured fish at larger artisanal landing sites and processing areas (TDRI unpublished data), it was noted that insect infestation of drying fermented fish and stored dried fish was a major problem. Several areas requiring research were highlighted. As a result, several collaborative projects between the local Fisheries Department, the Food and Agriculture Organization (FAO) and the Tropical Development and Research Institute (TDRI) were undertaken. The areas under investigation included improved processing (e.g. solar dryers, better salting techniques etc) and the use of insecticides.

In recent years, there has been considerable interest in the use of solar dryers as an improved method of drying fish in developing countries. By achieving higher temperatures and reduced relative humidities, solar dryers can increase drying rates, produce lower moisture contents in the final products and improve product quality compared with traditional sun drying. They can also provide protection against attack by the blowflies and beetles which cause considerable damage to dried fish. The principles of solar dryers and their advantages over traditional sun drying have been discussed in more detail elsewhere (Löf, 1962; Saulnier, 1976; Trim, 1982; Trim and Curran, 1983; Sachithananthan *et al.*, 1983).

The solar dryers so far used with fish have been of fairly low capacity (Chakraborty, 1976; Doe *et al.*, 1977; Meynell, 1978; Pablo, 1978; Deng *et al.*, 1979; Ismail, 1980 and 1983; Mercado Aguiar, 1980; Ahmed *et al.*, 1981; Richards, 1982; Camu *et al.*, 1983; Trim and Curran, 1983). It is only during the last few years that larger solar dome dryers have been investigated. Kent (1980) constructed a solar dome dryer (6 x 6m) in Mali. Then Sachithananthan (1984) and his co-authors (1983) tested a one-tonne capacity dryer in Aden and Bostock and Mosquera (1984) conducted trials with a 0.5-tonne capacity dome in the Galapagos Islands. This paper reports on the testing of a one-tonne prototype solar dome dryer, the design of which was prepared following the work in Aden. It was constructed on Brufut beach, the third largest artisanal landing and processing site along the Gambian coast.

EQUIPMENT AND METHODS

Solar dome dryer

The solar dome dryer is a prototype supplied by Clovis Lande Associates Ltd. (Gaza Trading Estate, Hildenborough, Kent, UK), following work carried out by FAO/TDRI in Aden by Sachithananthan, Trim and Speirs (1983 and 1984). The design is based on a horticultural greenhouse. It consists of clear plastic sheet stretched over a metal framework, with side and top vents, and a black concrete base sloping to both sides (Fig. 1). The black base is the heat collector. Air enters at ground level through the side vents and is heated in the heat collector areas. The heated air passes over the surface of the fish, removing water as vapour, rises and exhausts through the roof vents. All the vents are covered with black plastic mesh and have sliding panels to control the airflow and temperature within the dryer. The dome is divided into heat collection bays and fish drying bays, alternating with each other, and a central corridor for loading and unloading. The fish are usually hung on hooks which are fixed to removable drying beams in the drying bays. The solar dome dryer is available in a range of sizes; the model used in this experimental programme was 4.26 m wide x 7.56 m long x 2.0 m high. It had five bays along each side, three for drying and two for heat collection.

Sun drying racks

The double sloping rack was constructed from chicken wire spread over a wooden framework. One flat rack was built in the local traditional manner with a wooden frame and the central ribs from palm fronds for the drying table. The second comprised a concrete frame with chicken wire spread over it.

Fish preparation

Five different species were used during the drying trials: catfish *(Arius gambiensis* and *A. mercatorius)*; ladyfish *(Pseudotholithus senegalensis)*; bonga *(Ethmalosa fimbriata)*; shark and sea snails (both unidentified species). The main objective of the drying trials was to prepare dried products which were suited to the Gambian and Senegalese markets and, therefore, local preparation methods were followed. However, some possible improvements to the methods and alternative products were investigated to determine whether these would be acceptable to local consumers.

The products were all dressed according to local custom. The catfish and ladyfish were split while the bonga were descaled, gutted and gilled. The flesh of the sea snails (yete) was cut into four flaps and the gills were removed. Since very large shark were used, the flesh was cut into pieces averaging 700g in weight; these were scored.

The catfish were salted by four different methods: the traditional technique of sprinkling the surface with salt after the fish had been allowed to ferment (i.e. spoil) overnight; in saturated brine for 30 min; or in either 10 or 50° brine overnight. The ladyfish were soaked in saturated brine for 30 min. Bonga were either dry salted according to the local method or placed in 50° brine overnight. Dry salting involved filling the body cavity and 'coating' the skin with salt; the fish were then left in a pile overnight and any pickle which formed was allowed to drain away. Neither the shark nor the yete were salted.

For solar drying, the fish were usually hung from hooks on the drying beams. The split fish were hung from the tail using speats to stop them folding but bonga were hooked through the eyes. The traditionally salted catfish and the yete were more suited to drying on trays. For sun drying comparisons, the products were spread on one or more of the racks.

Operating procedure

With the exception of the shark, the products were dried until they were considered by local processors to be ready for the local market. The shark were dried until no further weight loss was found. During drying, batches of fish from each drying method were weighed at regular intervals (usually three times each day unless it was raining). During the course of the trials, a record was kept of the condition of the fish as they dried. At night, the solar dried fish were left in position in the dome and the sun dried fish were placed in a pile and covered with hessian sacking and plastic sheeting.

Weather permitting, measurements were taken at hourly intervals from 09.00 to 17.00 hours of the following: insolation using a solarimeter and integrator (Lintronic Ltd., 54-59 Bartholomew Close, London, UK); ambient and internal dryer temperatures with a temperature recorder (Grant Instruments (Cambridge) Ltd., Barrington, Cambridge, UK); ambient humidity with a whirling hygrometer (C.F. Casella and Co. Ltd., Regent House, Britannia Walk, London, UK); and wind speed using an anemometer (C.F. Casella and Co. Ltd). During the earlier trials, humidity inside the solar dome was also measured but this was discontinued to decrease the number of times it was necessary to enter the dryer and, thus reduce the entry of flies.

Final product analysis

For each batch of the final products from the drying trials, the flesh from several fish was minced and duplicate samples were taken from the pooled muscle for moisture and salt analysis. Moisture content was determined by drying 2-5 g sample in a convection oven at 105°C for 24 hours. The chlor-o-counter (Marius Instrumenten, P O Box 7018, Utrecht, Holland) silver electrode titration technique was used for the salt determination. Dried samples of each of the species investigated were also analysed for fat, protein and ash content (AOAC, 1965).

RESULTS AND DISCUSSION

The drying trials were carried out during June 1984 at the start of the rainy season. The frequency and amount of rainfall increased towards the end of the work and more dull weather was encountered. Generally, there was very hazy sunshine in the morning and it became either sunny or cloudy with rain in the afternoon. Over the 8-hr period when measurements of the operating conditions were taken, the mean ambient temperature was 31°C (range 25-35°C) and the relative humidity was 76% (48-89%). The total daily insolation averaged 16 MJ m^{-2} and the mean wind speed on Brufut beach was 11 km hr^{-1}.

The drying curves obtained during the trials are given in Figs. 2-5. The moisture and salt contents of the final dried products are given in Table 1 and the proximate analysis of the different species in Table 2. As can be seen from these results, the solar dome dryer did not perform as well as expected: very similar drying rates were obtained for sun and solar drying. Generally, 2-3 days of good drying weather were necessary to prepare a product suited to the local market. There were two main reasons for this poor performance: firstly, the nature of the raw material used to prepare the local product, guedja, and, secondly, the poor weather conditions.

Although the methods used for preparing guedja vary slightly with species and also between one processor and another, they all require fermented fish. Generally, the women processing guedja will buy spoilt fish in the late afternoon when it is cheaper. This will be dressed and salted immediately and left in a pile overnight on the drying rack before being set to dry the next day. If, for some reason, they have to buy good quality fresh fish, the women will bury it in clay pots in the ground and leave it overnight to 'ferment' (i.e., spoil). The following morning, the fish would be salted and set to dry on the racks. Consequently, the material which is to be dried is very soft and fragile. In addition, catfish, the main species used to prepare guedja, were about to spawn at the time that the dryer was being tested so that the flesh was even more delicate which worsened the situation. Fish which are salted by the traditional method of sprinkling salt on the surface are not suited to hanging in the solar dryer since the salt would fall off. Since this method also gives an uneven salt penetration, several brining methods were studied to determine which would be suitable for the local market. A fairly moist product is preferred.

During the first drying trial on catfish and ladyfish (Figs. 2A and 3A), the temperature in the solar dome was kept at 40-45°C on the first day of drying. Both species started to cook and break up during solar drying. As a result, the fish became misshapen, with gaping holes appearing due to the weight of the fish dragging on the hooks. Pieces of flesk broke off and fell onto the floor of the dryer. There was some evidence of case hardening in the solar dried ladyfish. Following this, during the drying of the brined catfish (Fig. 2B and C) an initial lower temperature was used (30-35°C) in the solar dome which was increased in stages to avoid cooking. It was concluded that the following drying regime should be followed when producing guedja in the solar dome:

Day	Ventilation	Temperture (°C)
1	Full	30-35
2	Fairly high	35-40
3	Low	40-45
4	Low	45-50

During the later trials, it was often found to be difficult to follow this regime due to the poor weather conditions. After the first drying day, the vents were kept closed in the morning until the required temperature was achieved in the dome. Unfortunately, the higher temperatures were regularly not reached until midday. The vents were then selectively opened, and towards the end of the afternoon closed again, to maintain the higher temperature. Consequently, drying at the required temperature was only possible for about 4 hours each day. While testing the earlier design of this dome, Sachithananthan *et al.* (1983) had similar problems with poor weather. They were able to exceed 40°C for about 8 hours each day (08.00 - 16.00 hours) and 45°C for about 5 hours (10.00 - 15.00 hours) only on fine sunny days.

Very poor weather was encountered during the drying of the traditionally salted catfish and unsalted yete. This trial had to be terminated prematurely due to the Eid el-Fitr religious holiday. Consequently, these products were not sufficiently dry for the local market: the former would have required about one more good drying day and the latter two more (Fig. 4A and C). Trays had been prepared for the solar dome and these were tested during this trial since the products are not suited to hanging in the dome.

The weight loss data for both the traditionally salted catfish and bonga should be treated with caution since some of the salt remaining on the fish could be lost during handling. All of the batches of sun dried yete samples contained at least one sample of 'melting' yete. This is a different species which is less acceptable to the local market and it is not always identifiable during preparation; the snail flesh starts to shrivel and turn black after a few hours' drying. Analysis of the 'melting' yete (Table 2) indicated that these had a different composition to the non-melting species so that the weight loss data will not give a true indication of the moisture loss from the main species during sun drying.

It was expected that using the sloping rack would produce the highest sun drying rates and the traditional rack the lowest with the flat rack in between these two. However, a comparison of the drying rate and moisture content data from all of the trials indicated that none of the racks appeared to perform consistently better or worse than the other.

It was found that heavy maggot infestation occurred if the entry of adult blowflies into the solar dome dryer was not restricted. The 10° brined catfish samples (Fig. 2C) were found to be heavily infested with blowfly maggots after three days in the solar dome and were discarded. The sun dried fish were also adversely affected but to a lesser degree.

Most of the adult flies entered the solar dome during loading. Following this, the temperatures inside the dryer would have been ideal for hatching of the blowfly eggs and far too low to kill the larvae (FAO, 1981). During sun drying most of the maggots would migrate inside the fish during the day and the incident sunlight would kill any remaining on the surface within a few hours. To overcome this problem, after unloading and washing the dome, the temperature inside was raised to 50°C for several hours before the next batch of fish were loaded. In bad weather when this was not possible, the dryer was sprayed inside with a domestic insecticide one hour before loading. During loading, as many beams as possible were taken into the dryer at a time; this was usually five beams between two people with a third person to open and close the dryer doors. The dome was then opened as little as possible during operation.

CONCLUSIONS

Sachitananthan *et al.* (1983) obtained higher drying rates using the earlier design of the solar dome dryer in Aden and were able to achieve a marked reduction in losses due to spoilage and insect infestation. In The Gambia, however, the solar dome dryer was less successful: very similar rates were obtained for sun and solar drying of several different products and blowfly infestation could be a problem. This was not considered to be a consequence of the minor changes in design.

There were two explanations for this poorer performance. Firstly, the raw material for the local dried product, guedja, is fermented (i.e., spoiled) before drying; it is very fragile and cooks and falls to pieces if it is dried at high temperatures initially. Consequently, it is necessary to start drying at ambient temperatures within the dome;the temperature is then increased gradually in stages to 50°C as the moisture content is reduced. During the later stages of drying when high temperatures could be used to increase the drying rate considerably, the product was sufficiently dry for the local market. Secondly, the dryer was tested at the beginning of the rainy season and the weather worsened during the course of the experimental period. It was often difficult to achieve and maintain the higher temperatures within the dome when they were required.

If steps were taken to kill all flies in the dome before loading the fish and care was taken to keep their entry into the dryer to a minimum during loading and operation, it was possible to decrease maggot infestation during drying. However, if flies did enter the dome, the conditions inside were ideal for hatching and development of maggots since high temperatures could not be used during the initial stages of drying. Under these circumstances, considerable losses were incurred. In Malawi, it was found that the performance of natural convection solar dryers in reducing blowfly infestation during the wet season was generally disappointing (TDRI unpublished data). They also found that some of the dryers tested achieved temperatures which were sufficiently high to reduce infestation but this led to cooking of the fish. A forced convection dryer was more successful in controlling infestation but reduced the drying rate and allowed some spoilage to occur. Several other workers (Doe *et al.*, 1977; Ahmed *et al.*, 1981; Ismail, 1983; Trim and Curran, 1983) have found natural convection solar dryers very efficient in reducing losses due to blowfly infestation during good weather. Haque (1982) reported that, in Bangladesh, further work undertaken with the solar tent dryer developed by Doe *et al.* (1977) and tested in the dry season produced similar results in the wet, humid season.

Work on the solar dome dryer in The Gambia is continuing. Several women from Brufut Village have been assisting with the processing and it is hoped that eventually they will be able to take over the commercial operation of the dryer. This further work will show whether improved drying rates may be obtained at other times of the year. It will also be used with non-fermented products which may be suited to drying at higher initial temperatures.

ACKNOWLEDGEMENTS

The authors wish to thank all of the Fisheries Department staff in The Gambia who assisted with the Project which would not have been possible without their hard work during construction and testing of the dryer.

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Table 1 Moisture and salt contents (wet weight basis) of final dried products

Species	Salting method	% Moisture		% Salt	
		Sun* dried	Solar dried	Sun* dried	Solar dried
Catfish	Traditional salting	39.92	50.03	28.81	27.80
	100° brine, 30 min	54.15	51.79	8.47	4.75
	50° brine, overnight	45.92	46.01	8.24	8.16
	10° brine, overnight	47.81	-	2.82	-
Bonga	Traditional salting	56.18	58.38	17.60	12.98
	100° brine, overnight	55.04	57.79	8.83	5.65
Ladyfish	100° brine, 30 min	58.79	64.28	3.30	7.19
Yete	Unsalted	60.51	66.39	3.35	3.51
Shark	Unsalted	30.95	36.44	3.23	4.15

* Mean of all sun dried products if more than one rack was tested.

Table 2 Proximate analysis (dry weight basis) of the species* studied

Species	% Fat	% Protein	% Ash	% Salt
Catfish	1.89	59.09	15.81	14.06
Bonga	4.16	68.37	20.30	16.46
Ladyfish	1.53	81.58	18.48	14.07
Shark	0.15	98.88	7.30	5.53
Yete	1.11	51.95	14.72	9.38
'Melting' yete	0.32	72.36	25.68	11.25

* The final products were used for the analysis.

LEGENDS TO FIGURES

Fig. 1 Solar dome dryer.

Fig. 2 Drying curves for catfish salted for (A) 30 min in 100° brine, (B) overnight in 50° brine and (C) overnight in 10° brine.

Fig. 3 Drying curves for brined (A) ladyfish and (B) bonga.

Fig. 4 Drying curves for traditionally prepared (A) catfish, (B) bonga and (C) yete.

Fig. 5 Drying curves for unsalted shark.

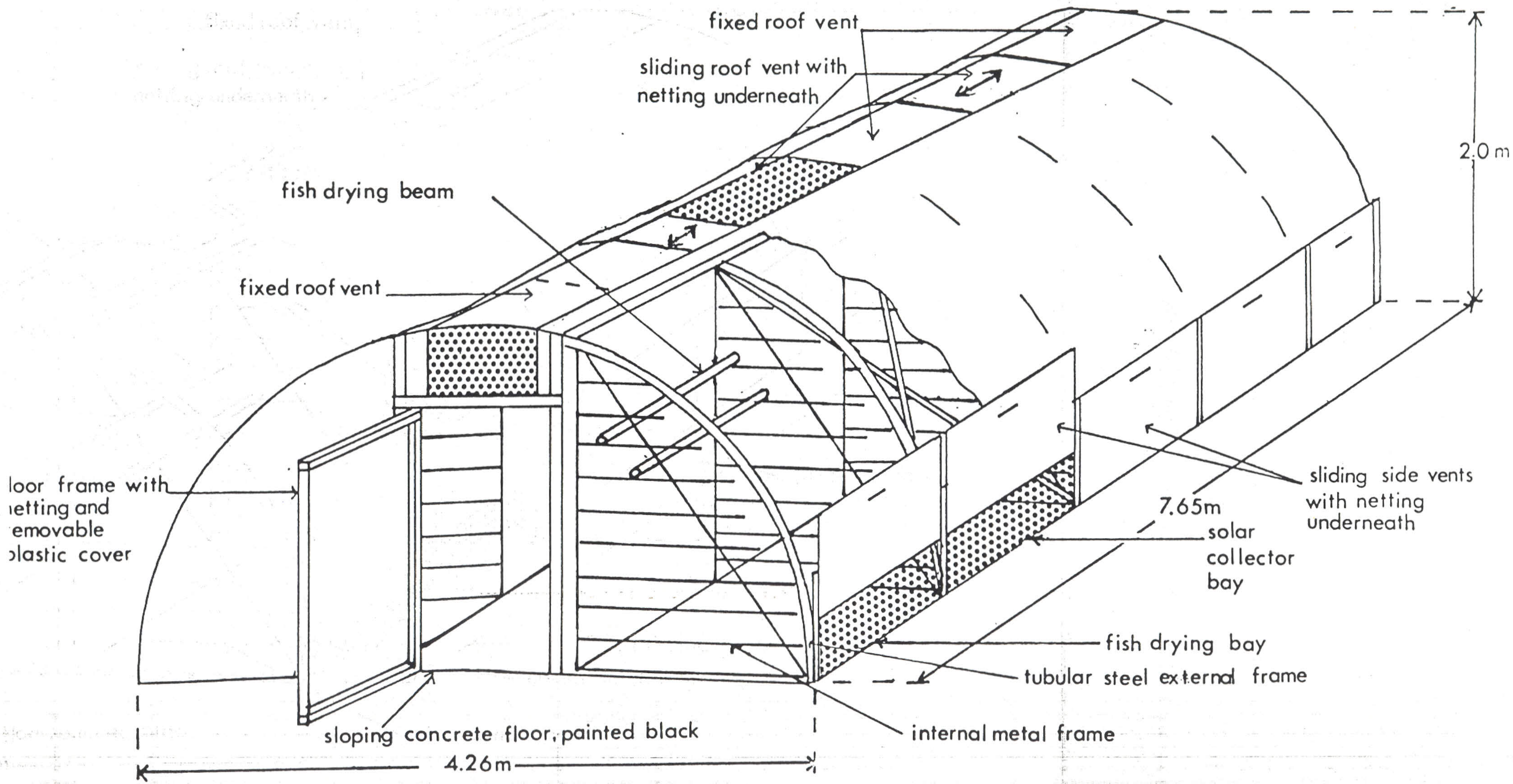
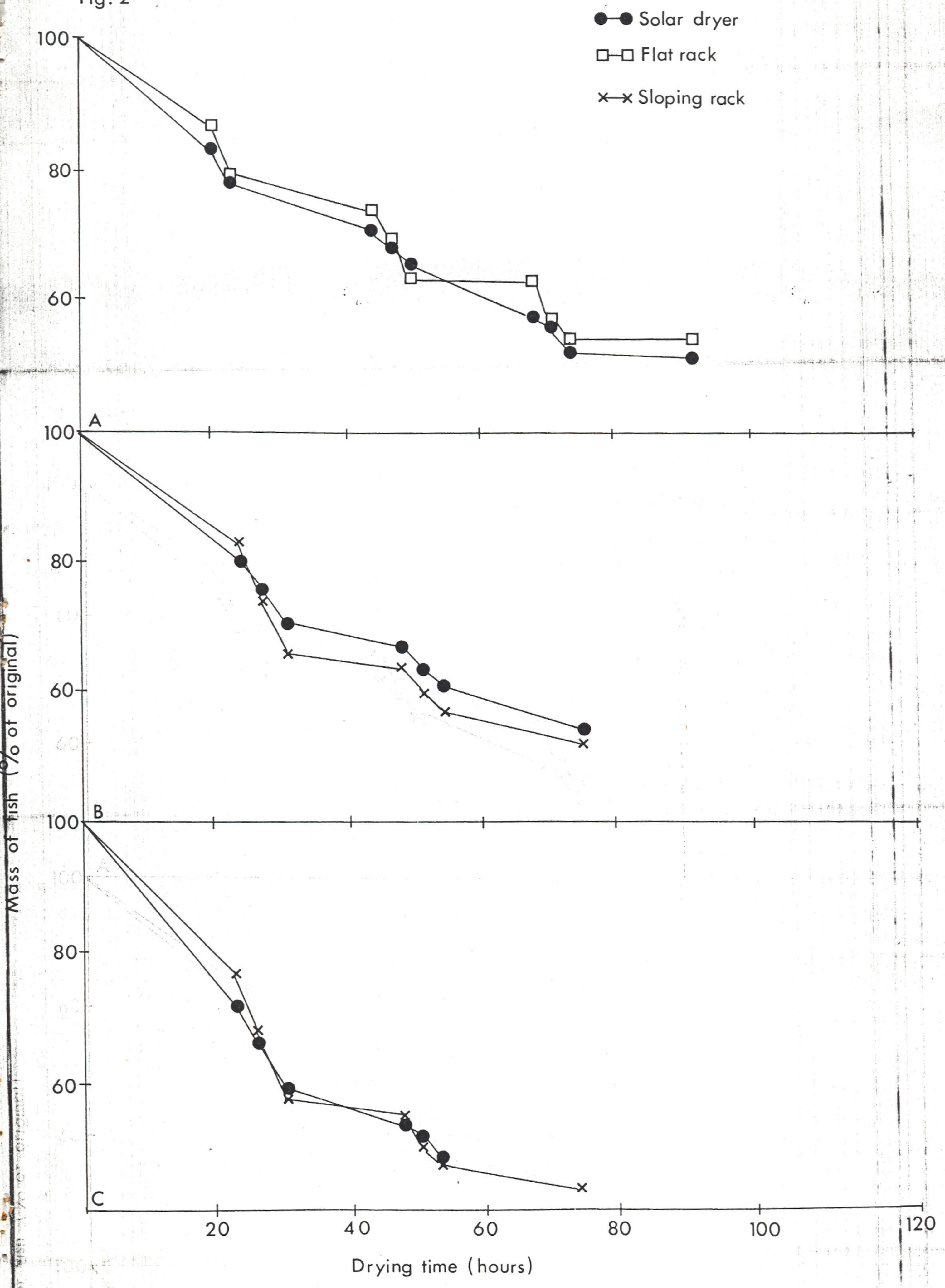

fixed roof vent
sliding roof vent with
netting underneath
fish drying beam
fixed roof vent
loor frame with
etting and
emovable
lastic cover
2.0 m
sliding side vents
with netting
underneath
7.65m
solar
collector
bay
fish drying bay
tubular steel external frame
internal metal frame
sloping concrete floor, painted black
4.26m

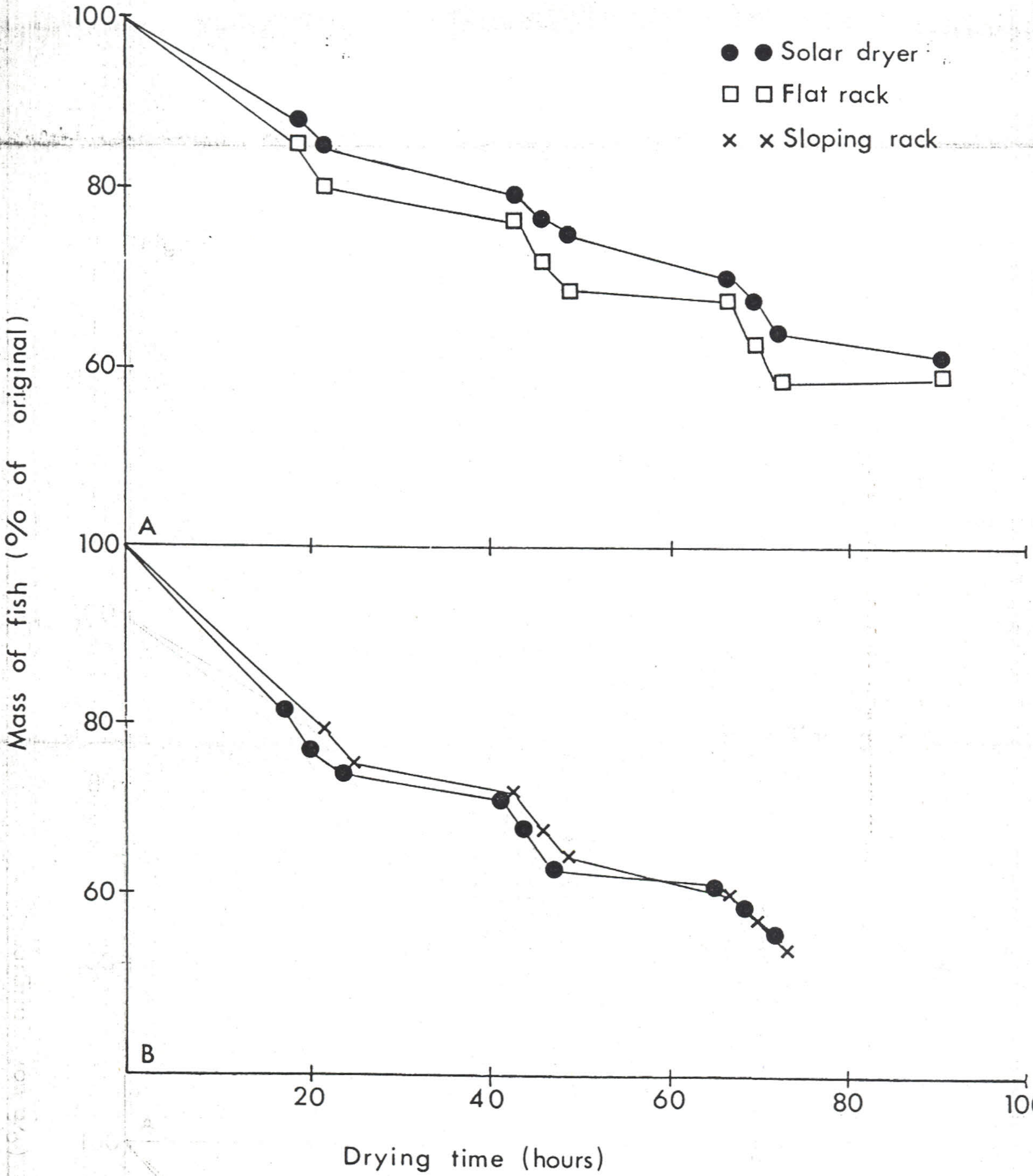
Fig. 1

Fig. 2



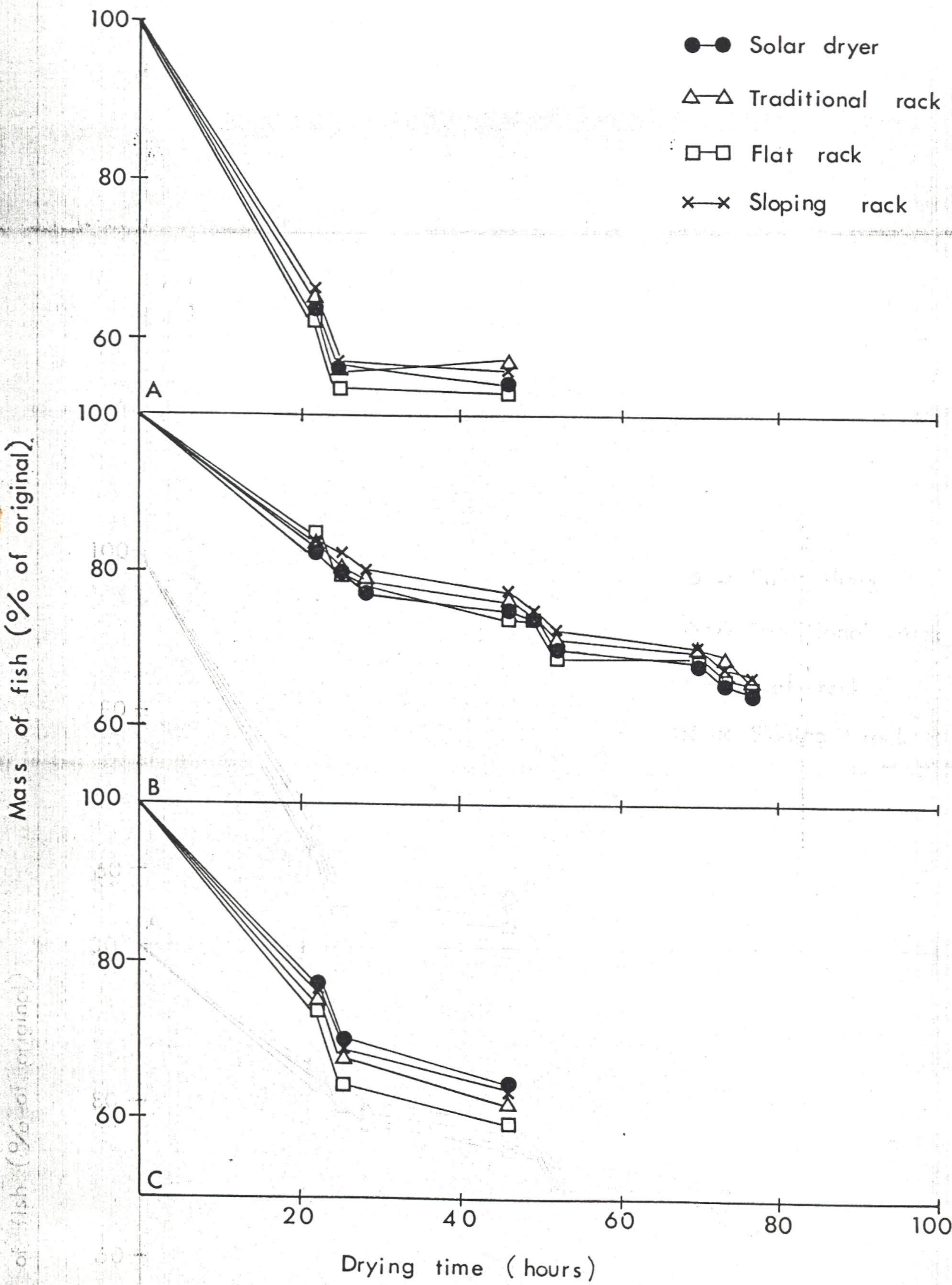
Solar dryer
Flat rack
Sloping rack
100
80
60
A
B
C
Mass of fish (% of original)
20
40
60
80
100
120
Drying time (hours)

Fig. 3



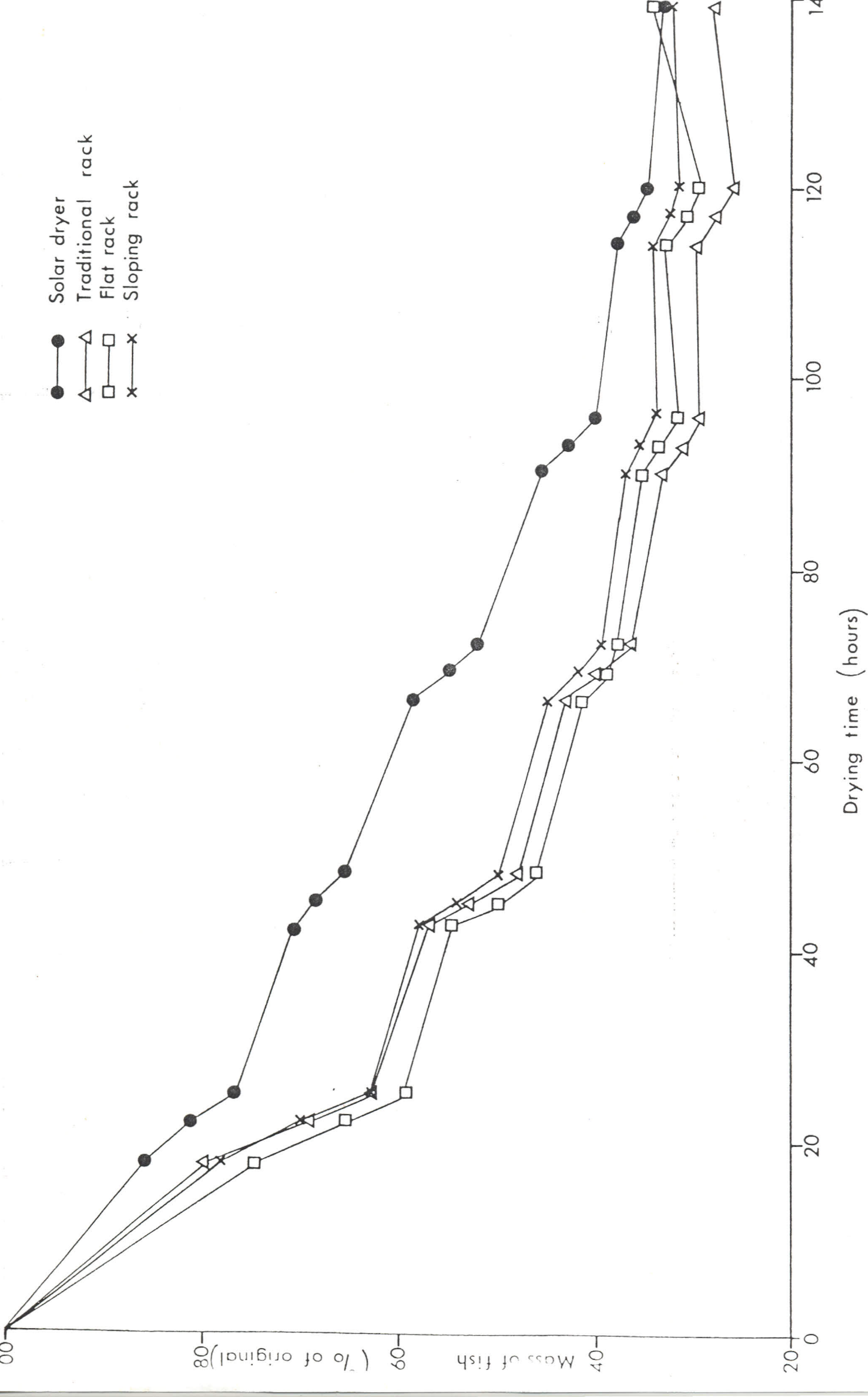
Solar dryer
Flat rack
Sloping rack
A
B
100
80
60
Mass of fish (% of original)
20
40
60
80
100
Drying time (hours)

Fig. 4



Solar dryer
Traditional rack
Flat rack
Sloping rack
100
80
60
A
B
C
Mass of fish (% of original)
20
40
60
80
100
Drying time (hours)

Fig. 5



Solar dryer
Traditional rack
Flat rack
Sloping rack
Drying time (hours)
Mass of fish (% of original)
0
20
40
60
80
100
120
140
20
40
60
80
00