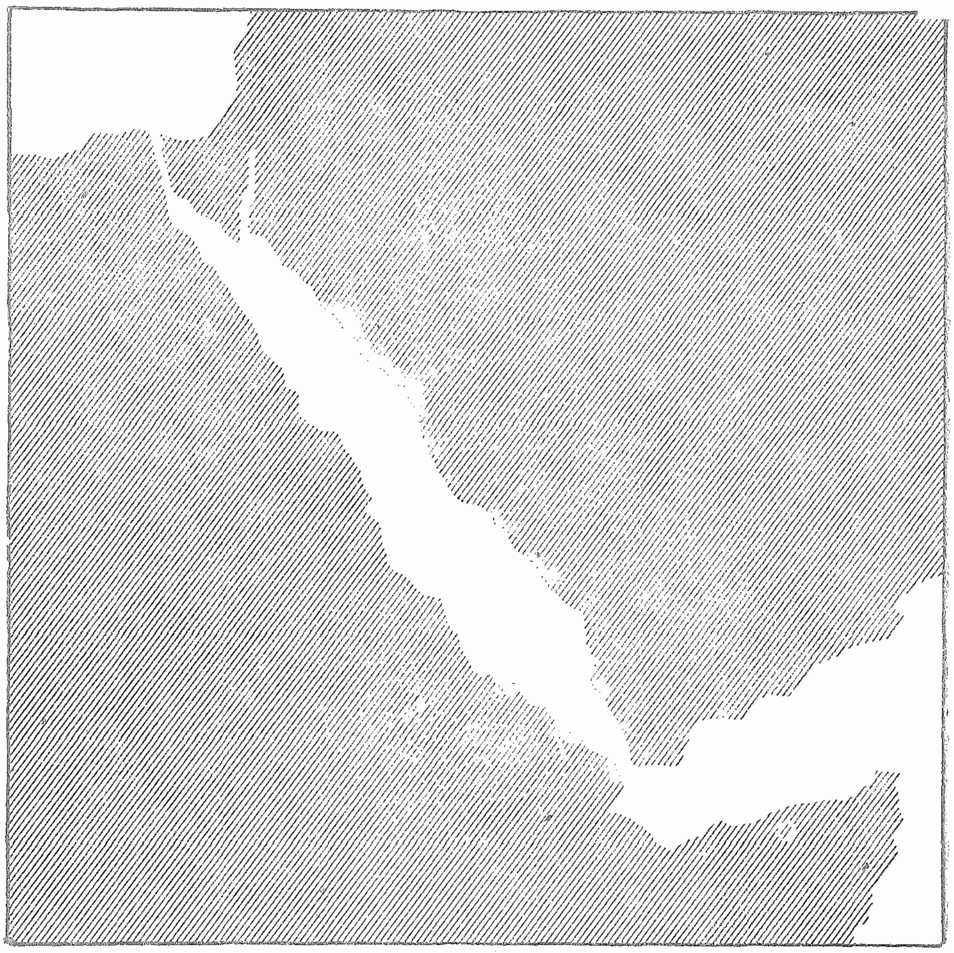
RAB 81/002/INT/18

DEVELOPMENT OF FISHERIES IN AREAS OF THE RED SEA AND GULF OF ADEN

A SOLAR DOME DRYER FOR DRYING OF FISH



UNITED NATIONS DEVELOPMENT PROGRAMME

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

RAB/81/002/INT/18

A SOLAR DOME DRYER FOR DRYING OF FISH

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Project for the Development of Fisheries in Areas of the Red Sea and Gulf of Aden

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Table of Contents

(2 Tables and 11 Figures)

A B S T R A C T

This paper presents the results, analysis, and discussion of four experimental trials conducted in Aden, comparing sun drying and solar dome drying of three species of fish. Solar dome drying is shown to be a realistic proposition compared with sun drying principally due to the very low losses achievable with solar dome drying. Technical feasibility of this methodology has been effectively demonstrated and should be supplemented by an economic feasibility evaluation. A description of the solar dome dryer is also presented.

INTRODUCTION

Sun drying of fish is the most prevalent traditional method of processing fish in the areas of the Red Sea and Gulf of Aden. Apart from consuming dried fish locally, countries like Yemen Arab Republic (YAR) and People's Democratic Republic of Yemen (PDRY) exported sun-dried fish until the early 1970's principally to Sri-Lanka. However, the production of dried fish has declined in the recent past, due to the introduction of ice, availability of low temperature storage facilities, increase in transport and communication facilities and the consequent supply demand for fresh fish. Also YAR and PDRY lost the valuable export market due to a variety of reasons but mainly those of poor quality and of problems associated with foreign exchange.

In recent years, fisheries authorities in the countries bordering the region are attempting to improve the methods of production and the quality of the dried fish, to reduce the losses during drying and storage as well as providing a quality product to the consumers in their own countries and for export.

Project for the development of fisheries in areas of the Red Sea and Gulf of Aden is assisting these countries in the region in:

a) improving the quality of dried fish,
b) extending the storage life of the product, and in
c) minimising losses of the product direct drying storage and distribution.

It has been considered that solar drying techniques might be more effective than the sun drying practices traditionally employed and a prototype solar dryer, was designed and constructed at the Caltex Fish Yard of the Ministry of Fish Wealth, Aden, PDRY. Initial trials with the solar dryer proved to be promising, but it was considered that before further investment was committed to the project, a technical evaluation should be undertaken to determine the effectiveness of the dryer and to recommend modifications if necessary.

COMPARISON OF SUN AND SOLAR DRYING OF FISH

The limitations of sun drying of fish and the potential advantages of solar drying techniques are briefly described below.

Sun drying is the simple expedient of placing fish in the open under the sun, is the traditional, most widely employed, easiest and still the cheapest method of drying. However, unhygienic conditions of the processing area, inadequate control of insect activity, exposure to preying birds, cats and dogs, higher relative humidity during drying and storage, poor packaging methods and poor storage facilities, can result in a product of poor quality and considerable losses can be incurred (FAO, 1981).

The potential advantages of solar drying techniques compared with sub-drying can be summarised as follows:

i) Drying time can be significantly reduced (Curran and Trim, 1982) due to higher temperatures attainable in solar dryers.

ii) Higher temperatures within the dryer, kill or greatly retard the activities of insects such as filth flies and beetles.

iii) Access by preying birds and cats is eliminated.

iv) Wind-born dust reaching the product is effectively excluded.

v) The combination of higher temperatures and faster drying time can limit harmful microbiological activity.

vi) Products with lower moisture contents are more easily attainable which can greatly increase effective storage time (Curran and Trim 1982).

THE SOLAR DOME DRYER

A solar tent dryer was developed in Bangaladesh some years ago (Doe et. al. 1977). This dryer was intended for individual fishermen dealing with a few kilograms of fish and has been used successfully in other areas (Anedeline, 1978, Curran and Trim, 1982, Richards, 1981). The principle of solar tent dryer (Figure 1) is easily appreciated; air enters at ground level along one or both sides, is heated within the dryer aided by the plastic base, and therefore rises and exhausts through outlet holes in the Apexes at each end. Fish are placed on the perforated racks which are either in the middle or on one side within the tent. A solar dome dryer (Figure 2) of larger capacity (6 x $6m^2$) was earlier attempted in Mali (Kent, 1980) but the trials were not conducted owing to logistical reasons.

In the Red Sea and Gulf of Aden region, large quantities of fish are available each day with individual fishermen for drying. The solar dome dryer built at Caltex Island, Aden, (Figure 2) was designed based on the principles of the solar tent dryer, for a handling capacity of 1000 kg of suitably prepared fish. Essentially, the dryer is based upon a modern horticultural green house consisting of clear plastic sheet stretched over a metal frame. The majority of the components were supplied by a green house manufacturer, (Covis and Lande Associates Ltd., Gaza Trading Estate, Hildenborough, Kent, United Kingdom). The green house design was modified by the inclusion of a black base and of inlet and outlet vents.

The black base is the heat collector. During the initial trials, a black plastic sheet was laid over a concrete base. Adults and larvae of insects found shelter in the shaded areas, folds and underneath of the plastic sheet. So during the second series of trials, this was replaced by black painted galvanished iron sheets, and the floor was sloped from the centre to the lateral sides.

The inlet vents are positioned along the full length of both sides, along the base. The outlet vent is positioned along the top of the dryer. Both inlet and outlet vents are fitted with fine plastic netting to reduce the entry of insects, windborne dust and animals. The inlet vent is also provided with a plastic flap fastened from the top to provide control of air flow. Cardboards slats are used to control the flow of air through the outlet vent. Strong winds sometimes forces air into the dome through the outlet vents.

Flat bed drying, eventhough is easy, would reduce the quantity (kg/m^3) of fish that could be dried inside the dome. Hanging fish on by their heads or tail would allow more air flow. Black paint coated wooden frames are installed within the dryer dividing it into ten bays; five on each side of the control accessway. Each bay is 1.6 m^2 on size, are left empty and used as surface for solar absorption and six are used as drying bays (Figure 3). Wooden beams with 26 hooks on either sidesare used to hang the fish. Each bay could accomodate upto 42 beams in 6 rows. Wooden trays for flat base drying could be accomodated, however, the size of the trays would narrow down in the upper rows.

EXPERIMENTAL METHODOLOGY

Four drying trials were carried out, using three species of fish, Horse mackerel - (Arabic: bathabath) - Scomber japonicus, Goat fish - (Arabic: abusinna) - Nemipterus japonicus and Cat fish - (Arabic: komal) Arius thallassinus. Fresh fish were not available readily; therefore supplies had to be obtained from the cold stores of the National Corporation for Fish Marketing (NCFM). Packs of frozen fish were transported by truck to the drying yard, thawed as quickly as possible in tanks of water, processed if necessary, packed with dry salt in concrete tanks (pickle - salting) and left overnight before being removed for drying. However, for the first trial fish had to be kept in the salting tanks for ca 42 hours. After salting the beams and/or trays were loaded in the processing area and then carried either to the solar dryer or to the sundrying area.

Bathabath were dried in the first trial in four batches; on hooks and on trays inside the solar dome dryer; on hooks and on wooden slated tables for sundrying. The Caltex drying yard uses wooden slated tables for sundrying fish usually. Bathabath were also used in the second trial with fish being dried on hooks both inside the solar dryer and by sundrying. In the third trial abusinna were used. Two batches were dried on hooks in the solar dryer; one with the beams sidely spaced and the other with the beams closely packed. A third batch was sundried on hooks. Komal were used in the fourth trial; one batch on hooks in the solar dryer, with the beams widely spaced and the other also on hooks by sundrying. Table 1 provides detailed data on the techniques used in the four trials.

Drying rates were monitored both by regularly weighing selected batches of fish and by measuring muscle moisture content, using an infrared moisture balance. Air temperatures both outside and at various positions within the dryer were continuously recorded during daylight hours using a six-point chart recorder. Temperature and humidity recordings were also made at selected locations using chart thermo-hygrographs. Cumulative measurements of insolation were obtained with a dome solarimeter and integrator and those of wind speed with a cup anenometer.

In addition to these physical measurements, careful observations were made of the condition of each batch of fish as it dried and also of the effects of flies and beetles upon the fish.

RESULTS AND DISCUSSION

It was undortunate that for most of the trial period extremely unusual climatic conditions were encountered; an average insolation of 9.5 $MJ.m^{-2}.day^{-1}$ was recorded for the period of 9 - 21 February compared with a usual figure of about 20 $MJ.m^{-2}.day^{-1}$, (Howell and Bereny, 1979). However, for the last few days of the trials, more typical weather was experienced and an indication obtained of the probable performance of the solar dryer under typical regional conditions.

The air temperature recorded at the upper levels within the dryer on fine sunny days, with insolation of about 15 $MJ.m^{-2}.day^{-1}$ and with the flaps over the inlet vents closed, exceeded 40°C for about 8 hours a day (0800 - 1600 hours) and 45°C for about 5 hours (1000 - 1500 hours), during which durations the ambient air temperature was about 29 - 33°C (Table II). Temperature of the air inside the dome varied within 1-3°C with lower temperatures near the base and the door area, and with higher temperatures at the center and at the upper layers. Insolation, rate of air flowing through (depending on the condition of the fish load) are factors directly influencing the air temperature inside the dome.

Drying curves for the four trials are illustrated in Figures 4 - 10; Figures 4, 5, 6, and 7 are plots of the loss in weight of selected batches, and Figures 8, 9, and 10 are plots of the change in muscle moisture content or randomly selected fish. It must be noted that with the exception of the fourth trial, the drying curves were untypical because of the unusually inclement weather. Some of the sun dried batches were prematurely terminated, particularly in the first three trials because of the excessive insect infestation and/or putrefaction.

The rate of drying was generally greater in the sundried fish during the first two days than that of those inside the solar dome. This was owing to the reduction in the speed of the air flow inside the dome. However, the drying rate during the later stages, i.e. at low moisture contents, was greater inside the dome than that of outside. This can be observed from the drying curves. This result is in agreement with the generally accepted drying theory (Waterman, 1976) in which internal moisture diffusion is considered the rate controlling factor at low moisture levels. Diffusion is very temperature dependent and therefore the higher temperature attained within the solar dryer would effect higher drying rates.

From Figure, 4 it can be seen that the rate of drying for fish hung on hooks was considerably greater than the average drying rate of fish loaded on a tier of three trays. Figure 11, illustrates the drying curves for fish on each of these three trays. As might be expected the drying rate of fish spread on the uppermost tray was significantly greater than that of the fish on the middle tray which in turn was appreciably greater than that of the fish on the bottom trays.

Insect activity during the trials presented an interesting comparison. On day when insolation was low, the insect activity was high. Batches of sundried fish hung on hooks were eaten up by the larve of Chuysonya megacephala Fab., the common filth fly. Most of the sundried fish were lost to this larvae during the initial drying period. Eggs were laid on the exposed parts of the fish during salting. The eggs hatched into larvae during the first two days of drying. Eggs were also laid during the first day of drying. However when insolation was relatively high, the insect activity was reduced. Inside the dome, filth flies entered through the door while loading. Also eggs laid during salting hatched into larvae, which at temperatures above 40°C swooned to the floor of the dome dryer to creep towards cooler and shaded area. Conducted heat at the metal base, even in shaded areas, killed most of the larvae falling from the floor to be killed. Few larvae pupated into adults however to be killed at higher temperatures later. Entry and exit of adult flies was effectively restricted by plastic mesh. Losses due to filth fly activity inside the solar dome dryer was low during the trials.

The beetle Dermestes frischii kugelmann, entered the processing area with the powdered salt. These beatles were found in fish inside the salting tank. Adults and larvae were not observed during sundrying on the hanging fish, whereas they were found inside the solar dome dryer. The adults clustered around the mesh receiving cooler air during day time when temperatures inside the dryer became intolerable. The number of larvae and adults of beetles dying increased day by day.

It is unrealistic to expect complete elimination of insect infestation within the dryer; but there were very promising indication that the insect population inside the dryer could be kept to reasonable limits. During the initial trials with black plastic base, the insects tents to hide themselves in small openings, crevices, folds of plastic and shaded areas. Also there was a tendency for insects to hide in the cracks of the wooden framework and by the inlet vents. Better control of insects could be achieved with the limited and indirect use of insecticides (not on the fish) by fumigating the dryer before and after use and other good housekeeping practices.

The lower quality of dried fish produced in the region owing to adherence of dust and sand to the product is the result of sun drying fish in the open sand, exposing them to the frequent sand storms and dust storms. The solar dome dryer provided the required cover to prevent such contamination. The product from the solar dome dryer had neither sand nor dust on it. Losses owing to drying in the open sand or on wooden slated tables as in the Caltex Drying Yard, are heavy mainly due to the prying of birds, cats and dogs. Bathabath dried on the first trial both on hooks and on the slats suffered greatly from these by sea gulls, and cats resulting in total losses. Birds, cats, or dogs could not enter the solar dome dryer and unlike in the sun drying method the total quantity kept for drying is completely recoverably as dried product.

Lower levels of moisture content were achieved for products from the solar dome dryer then were achieved in the sundried products. Moisture reabsorption was evident during the later stages of drying of Komal inside the solar dome dryer; the product had droplets of water lining the lowest portion of hanging fish during dawn, and the weights increased by 2 - 3% during dawn from that of the previous dusk reading.

The most striking feature of the trials was the difference in quality of the dried fish produced in the solar dome dryer and by sundrying. With the exception of abusinna, in the third trial the quality of the fish dried on hooks in the solar dome dryer was extremely good being well and evenly dried, of pleasant odour and little evidence of rancidity or of microbial or insect attach. The quality of solar dome dried bathabath and Komal could be considered to be superior to that generally produced in the Red Sea and Gulf of Aden region. The yield of good quality solar dome dried fish was therefore extremely high with only a small proportion of the product being considered as not of the highest quality. However, in the third trial with abusinna in which the beams were closely packed in a drying bay, it was found that the fish in the middle of the pack dried very slowly due probably to poor airflow and excessive localised humidity around the fish resulting in considerable losses (about 50% due to putrefaction).

As might be expected the quality and yield of sun dried fish was considerably lower (Table 1) although this was no doubt exacerbated by the untypical weather. Bathabath dried in the first trial both on hooks and on the slats suffered greatly from insect infestation, particularly filth flies. Fish sun dried in subsequent trials in better weather did not suffer so greatly from insect attach but overall quality of the dried product was poorer than that of solar dried fish. Officials of the Ministry of Fish Wealth, Aden estimated that sun drying losses could be as high as 40 - 50% and of a general quality lower than that obtained in the solar dome dryer. The product obtained by sun drying during the trials was almost certainly of significantly higher quality than the sun dried product.

It should be noted that all the trials were carried out using thawed frozen fish. During freezing and subsequent thawing it might be expected that some degree of protien destruction would occur resulting in a small loss of moisture. Drying times with freshly caught fish might therefore be expected to be slightly longer than those recorded in the trials. Despite having to use frozen fish for the trials it was still possible to obtain solar dried fish of the highest quality.

The quantity of fish that could be loaded into the solar dome dryer for drying depends on the size of the fish and its preparation. It is evident from the trials that for fish above a certain size, i.e. 150 mm length, drying on hooks is the msot efficient method of utilizing the space available. The thickness of fish should not exceed 15 - 17 mm if it were to be hooked whole. All fish above this thickness are split and scarified for salting and drying. Bathabath and abusinna were hooked as whole. Komal was split and scarified prior to salting for hooking.

Two fish per hook increased the density, when the hangers were arranged close to each other. With 150 - 175 kg of fish in each of the six bays will be the optimal quantity, for whole or prepared fish. With such density, it can be expected that fish could be dried to a moisture of 25% in about four days in normal weather. Allowing one day for unloading/reloading, in an operating cycle of 5 days, the dryer is capable of 5 days, the dryer is capable of a throughput of 200 kg of fish per day.

Solar dome dried fish was observed to be devoid of insects during the post-noon hours (1300 - 1500 hrs) as most of the insects persumed to have been killed or in hiding. Well dried products were packaged in polythene bags during these hours to avoid any insect reaching the package along with the product. Once the polythene bags were sealed the chances of insects reaching the product were reduced, unless storage conditions permit insects to drill through to polythene package. However, eggs laid by the beetles Dermestes frischii on the product before packaging hatched out inside the package and very few were still seen inside the package after 3 months of storage of the solar dome dried fish.

CONCLUSIONS

1. A modified horticultural greenhouse can be used to successfully dry fish.
2. Shorter drying times inside the solar dome dryer mean marked reductions in losses due to biochemical and bacterial action.
3. Restricted access and an unfavourable environment within the solar dome dryer reduces insect infestation and associated losses.
4. The elimination of birds and animals results in prevention of theft of fish and the associated losses.
5. Hanging fish on hooks for drying inside the dome is better than arranging them on layers of tray.

RECOMMENDATIONS

1. The optimum size of a solar dome dryer for commercial purposes will be one that takes in a maximum load of + one ton of prepared fish, at a time.
2. Fishes of 15 cm and longer should be used for hooking. If the thickness of the fish exceeds 20 mm, the fish should be split before hooking.
3. Limited use of powdered insecticide is recommended for sprinkling around the base of the dryer. However, knowledgeable persons should be consulted regarding type, quantity and method of use of any insecticide.

4. The door of the dryer should as far as possible be kept closed.
5. The vents size should be adjusted to allow maximum air flow through the fish during the first two days of drying, the temperatures should range between 45°C and 50°C during the final stages of drying.
6. Removing the product for packaging should always be carried out during the afternoons, to avoid insects in the product.
7. The heat collection area should always be kept free from obstacles. It should not be used as a storage area. Shade producing articles should not be placed on top of the dome plastic.
8. Good house-keeping practices are essential to achieve efficient use of the dryer. Proper maintenance and care of the various parts of the dryer are equally essential.

ACKNOWLEDGEMENTS

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TABLE 1

Experimental Trials

Trial	Species	Drying Method	Quantity Used, kg		Salt Used kg	No. of Beams/ Trays	Spacing m	Dried Fish	
			Fresh	Prpd				Mass kg	Loss* %
1	Batabath	1. Solar/ Hooks	-	280	--	48	0.3	13.2	1-2
		2. Solar/ Trays	N/R	36	N/R	3	0.25	R/T	-
		3. Sun/ Hooks	N/R	28	N/R	5	0.3	R/T	ca100
		4. Sun/ Slats	N/R	10	N/R	1	-	R/T	ca100
2	Batabath	1. Solar/ Hooks		47		8	0.3		0
		2. Sun/ Hooks		7		1	0.3		
3	Abusinna	1. Solar/ Hooks	405	17	148	3	0.3		0
		2. Solar/ Hooks		242		43	0.15		50
		3. Sun/ Hooks		17		3	0.3		
4	Catfish	1. Solar/ Hooks	351	150	123	21	0.3	92	0
		2. Sun/ Hooks	16	7		1			

N/R - not recorded

R/T - Termination of trial due to excessive insect, putrefaction etc.

* Loss of fish defined as proportion of dried product considered as of unsaleable quality

Table II. Temperature (oc) inside (upper layers) and outside the Solar dome during the duration of the trials

Date	Inside (upper layer)		Outside		Number of hours above 40°C inside
	Min	Max	Min	Max	
7.2.83	--	44.5	--	--	---
8.2.83	25	45	25	32	8
9.2.83	24.5	47	25	34	7
10.2.83	25	37	25	30	---
11.2.83	21	33	22	29	---
12.2.83	23.5	46	25	33	8
13.2.83	24	52	25	33	8.5
14.2.83	24	42	25	30	6
15.2.83	22.5	44	21.5	30	6
16.2.83	23	45	23	31	6
17.2.83	23	49	23.5	32	8.5
18.2.83	24	47	23	34	8
19.2.83	25	45	25	31	5
20.2.83	24	45	--	--	2
21.2.83	--	--	--	--	---
22.2.83	23	39	--	--	---
23.2.83	23	47	--	--	9
24.2.83	23.5	47	--	--	8.5
25.2.83	24	47	--	--	8.5

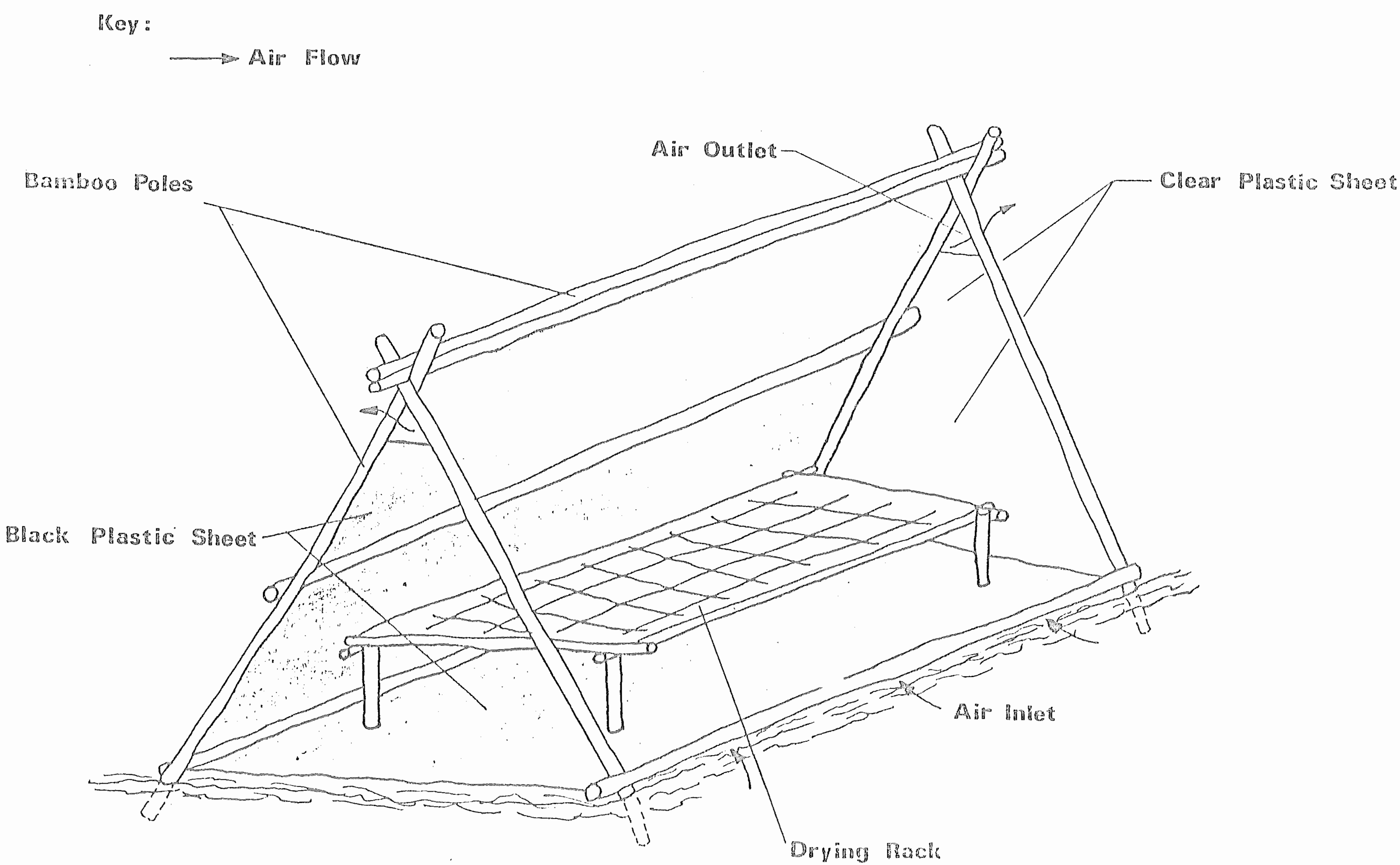

FIGURE 1 DIAGRAM OF THE POLYTHENE TENT DRIER (DOE et al, 1977)

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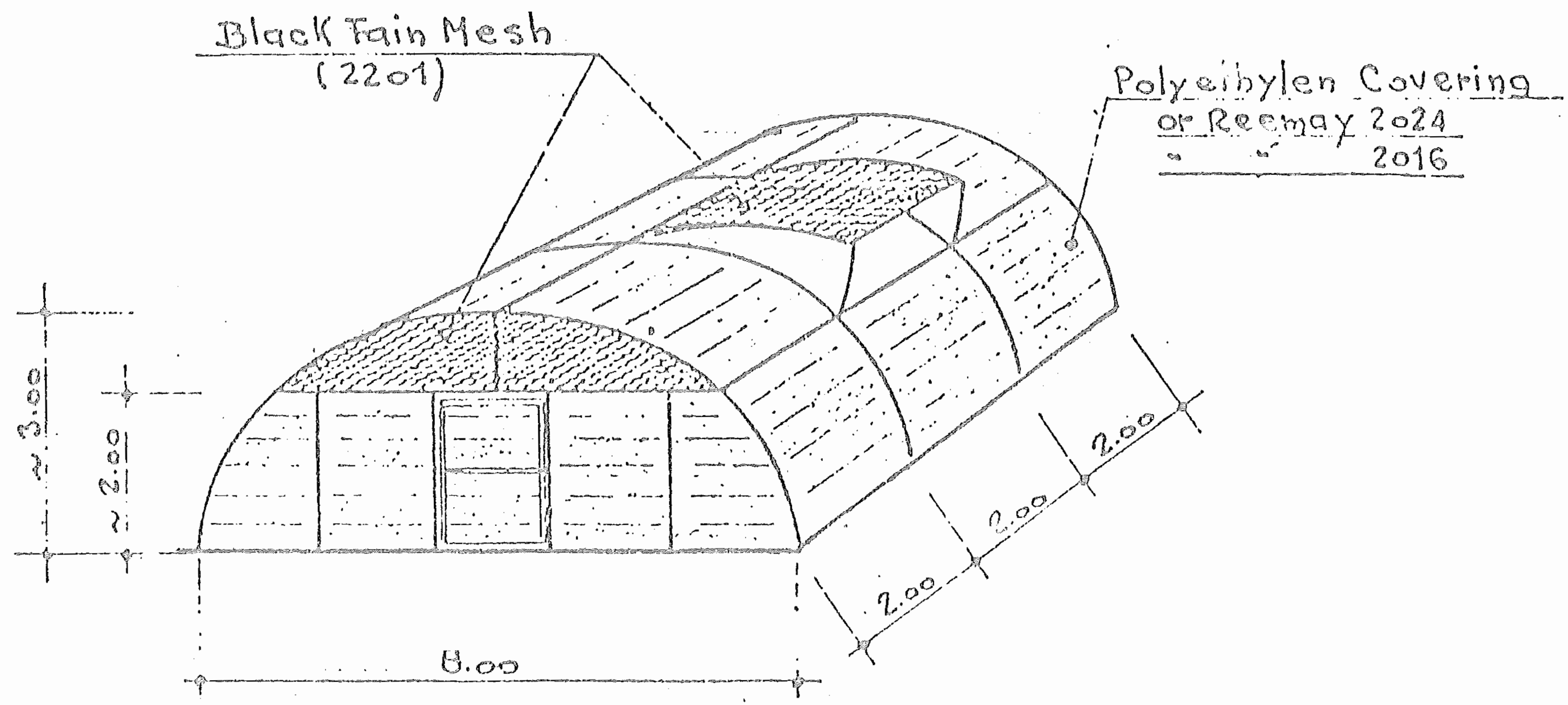


Fig. 2 Diagram of the construction of the greenhouse/tent in Mali (Kent, 1980)

All Dimensions Approximate

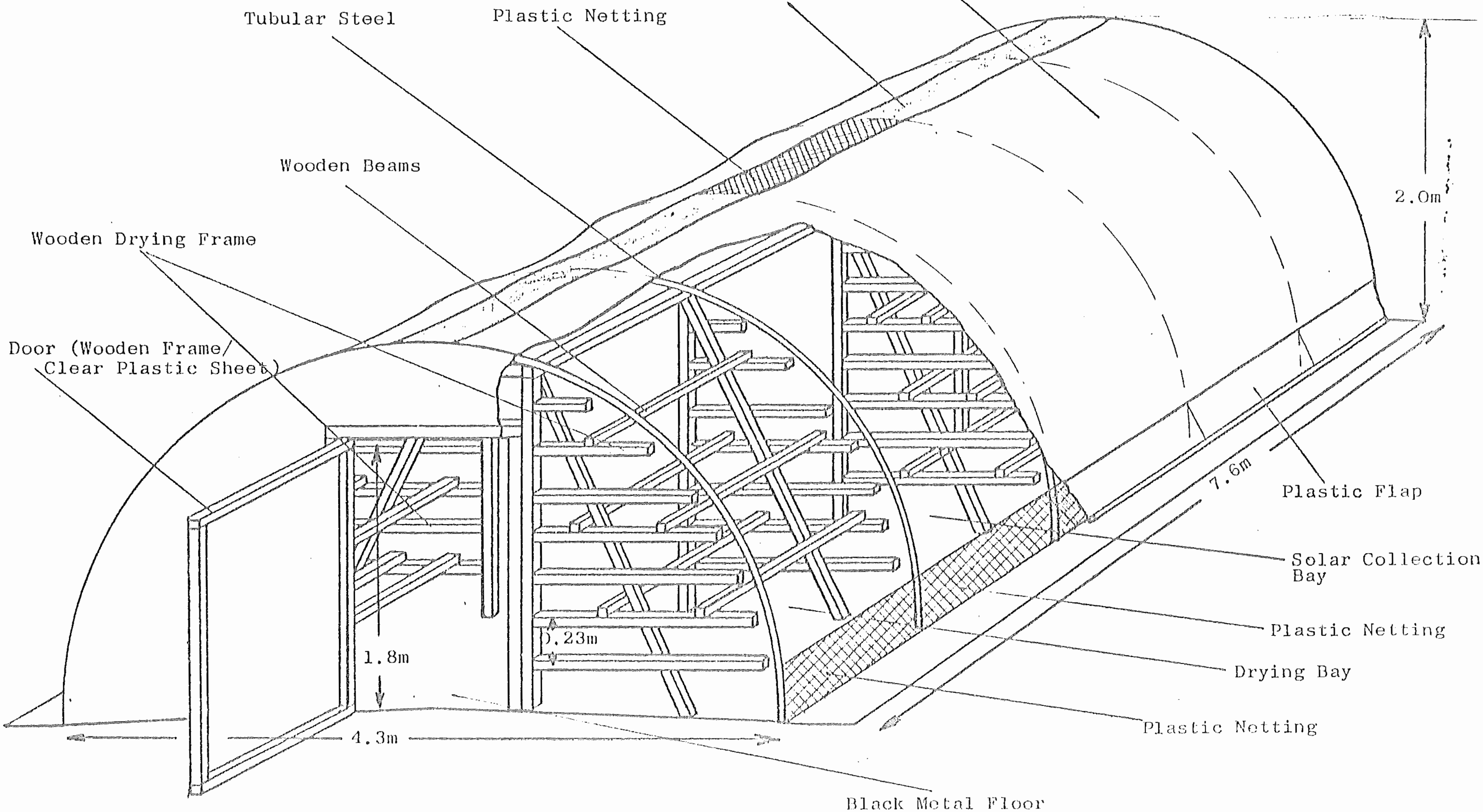


FIGURE 3 - Solar Dome Dryer - Aden

Figure 4

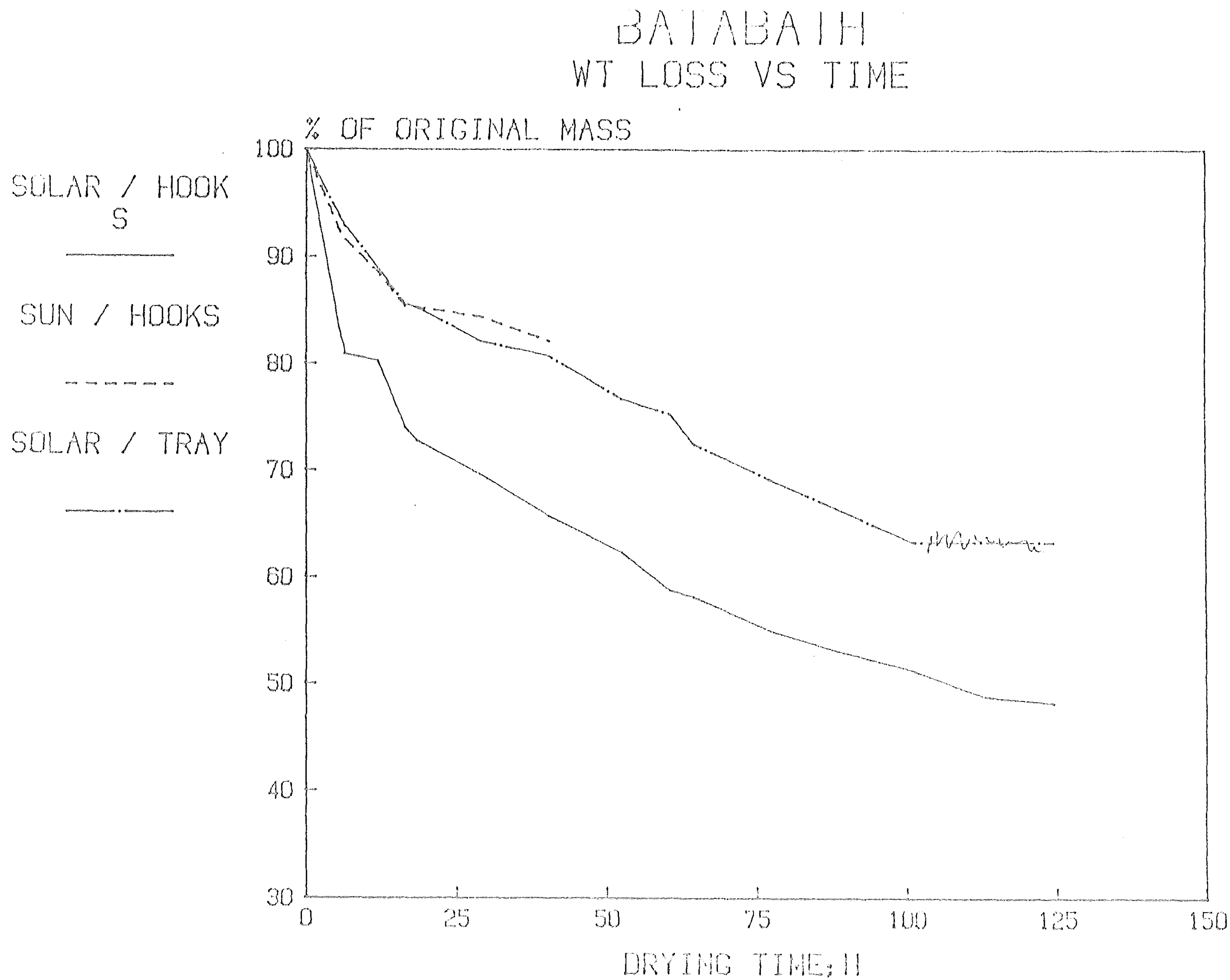

BATABATH
WT LOSS VS TIME
% OF ORIGINAL MASS
100
90
80
70
60
50
40
30
0
25
50
75
100
125
150
DRYING TIME; H
SOLAR / HOOK
S
SUN / HOOKS
SOLAR / TRAY

Figure 5

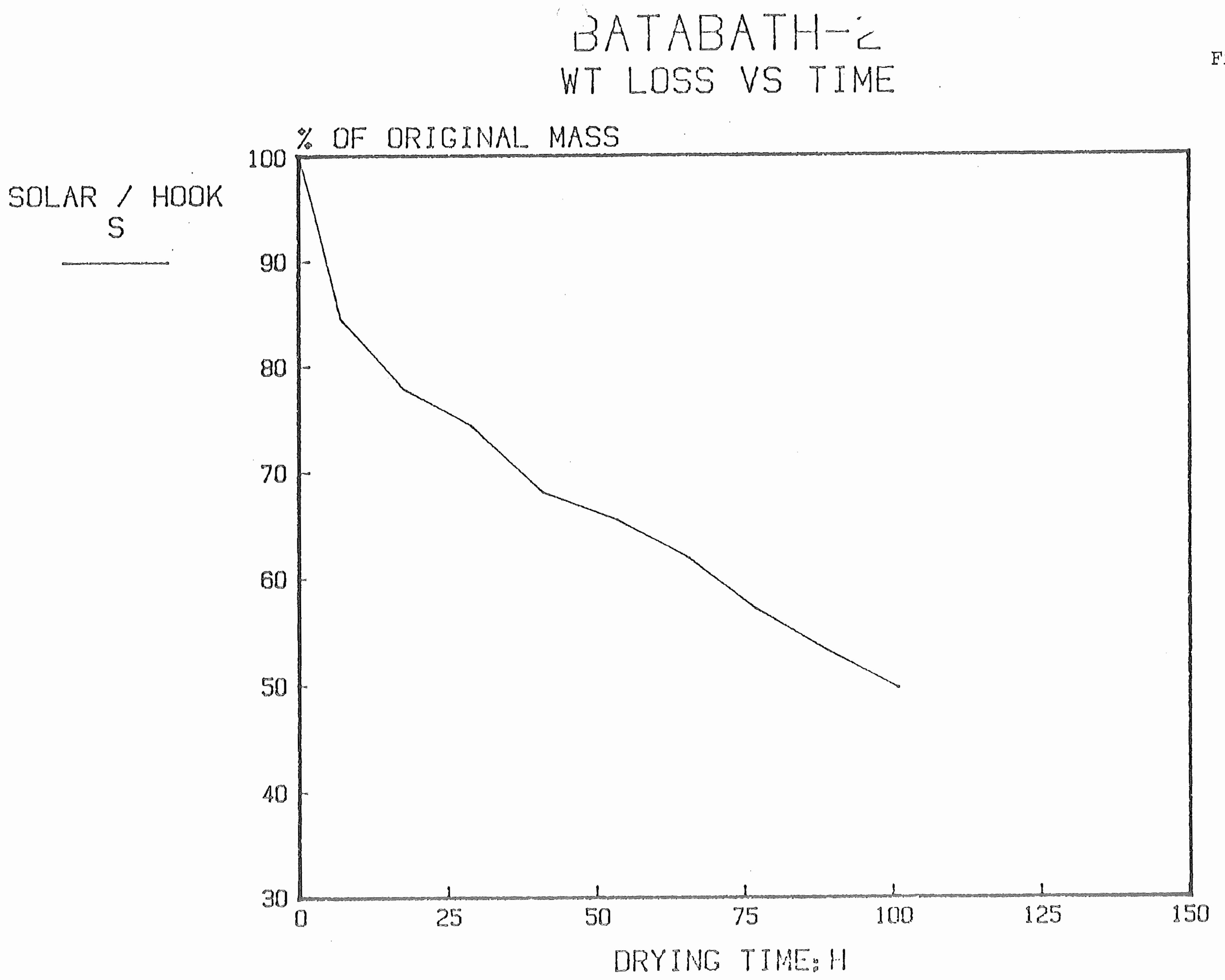
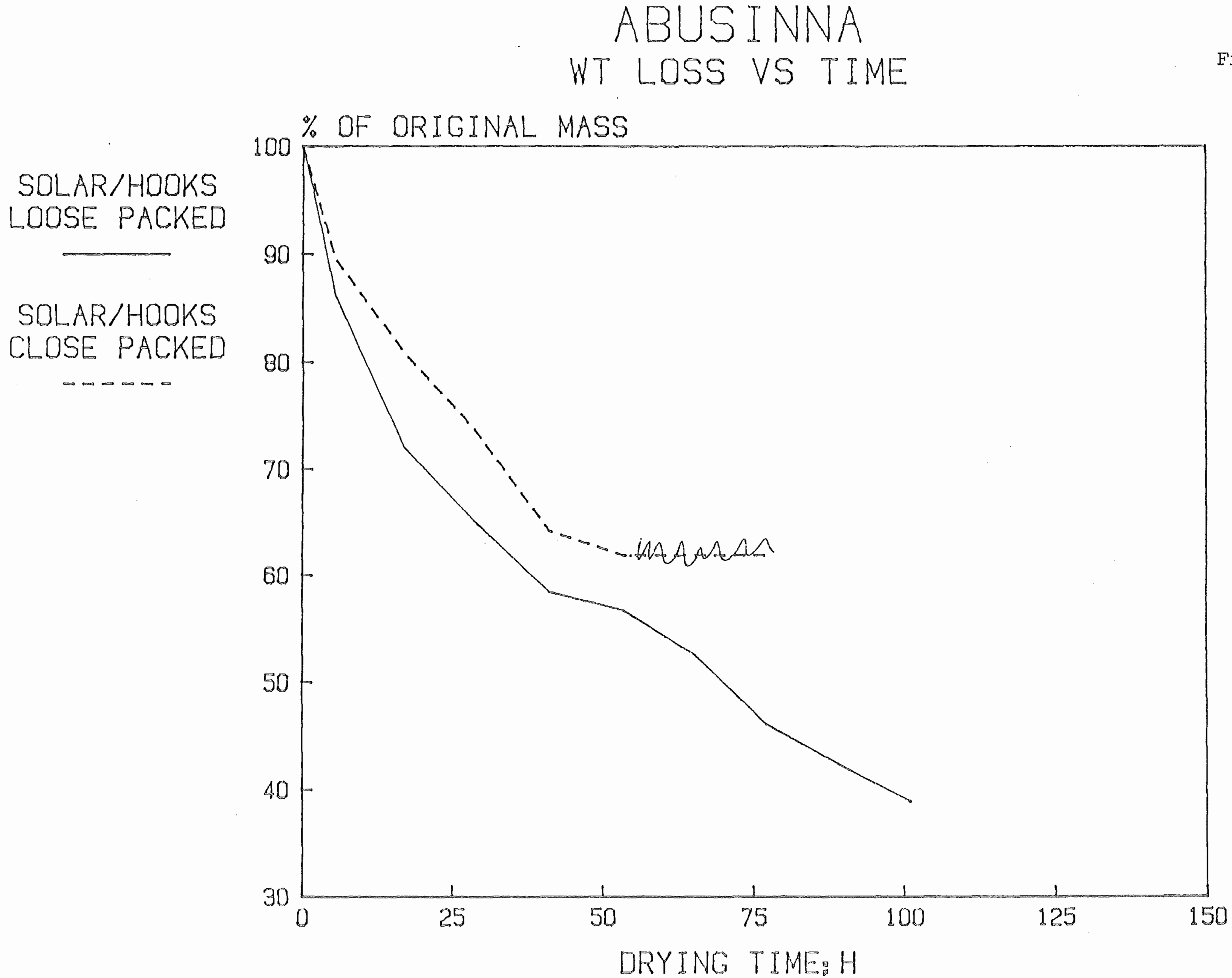

BATABATH-2
WT LOSS VS TIME
% OF ORIGINAL MASS
SOLAR / HOOK
S
100
90
80
70
60
50
40
30
0
25
50
75
100
125
150
DRYING TIME; H

Figure 6


ABUSINNA
WT LOSS VS TIME
% OF ORIGINAL MASS
SOLAR/HOOKS
LOOSE PACKED
SOLAR/HOOKS
CLOSE PACKED
100
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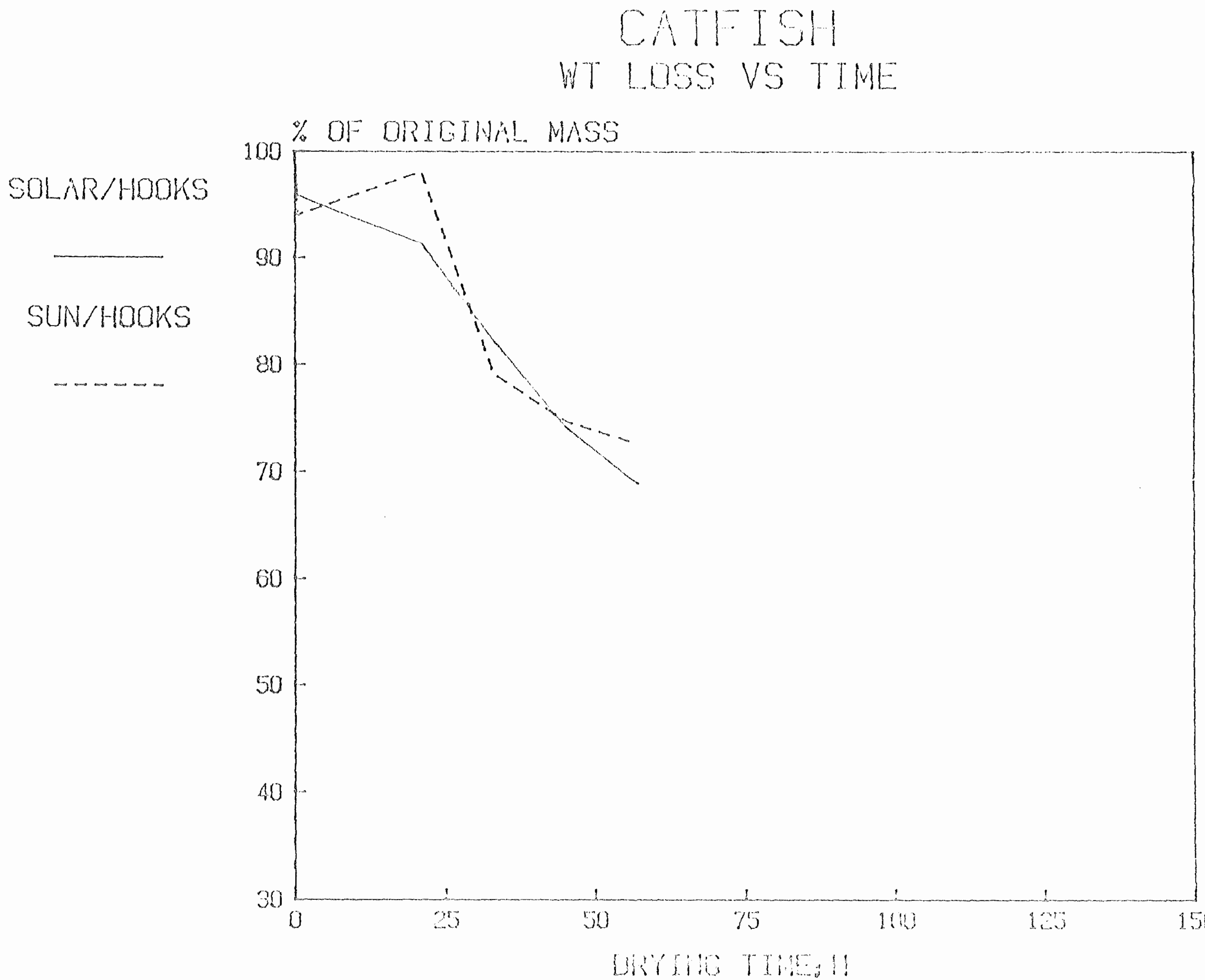
DRYING TIME; H

Figure 7


CATFISH
WT LOSS VS TIME
% OF ORIGINAL MASS
SOLAR/HOOKS
SUN/HOOKS
100
90
80
70
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40
30
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25
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125
150
DRYING TIME, H

Figure 8

BATABATH

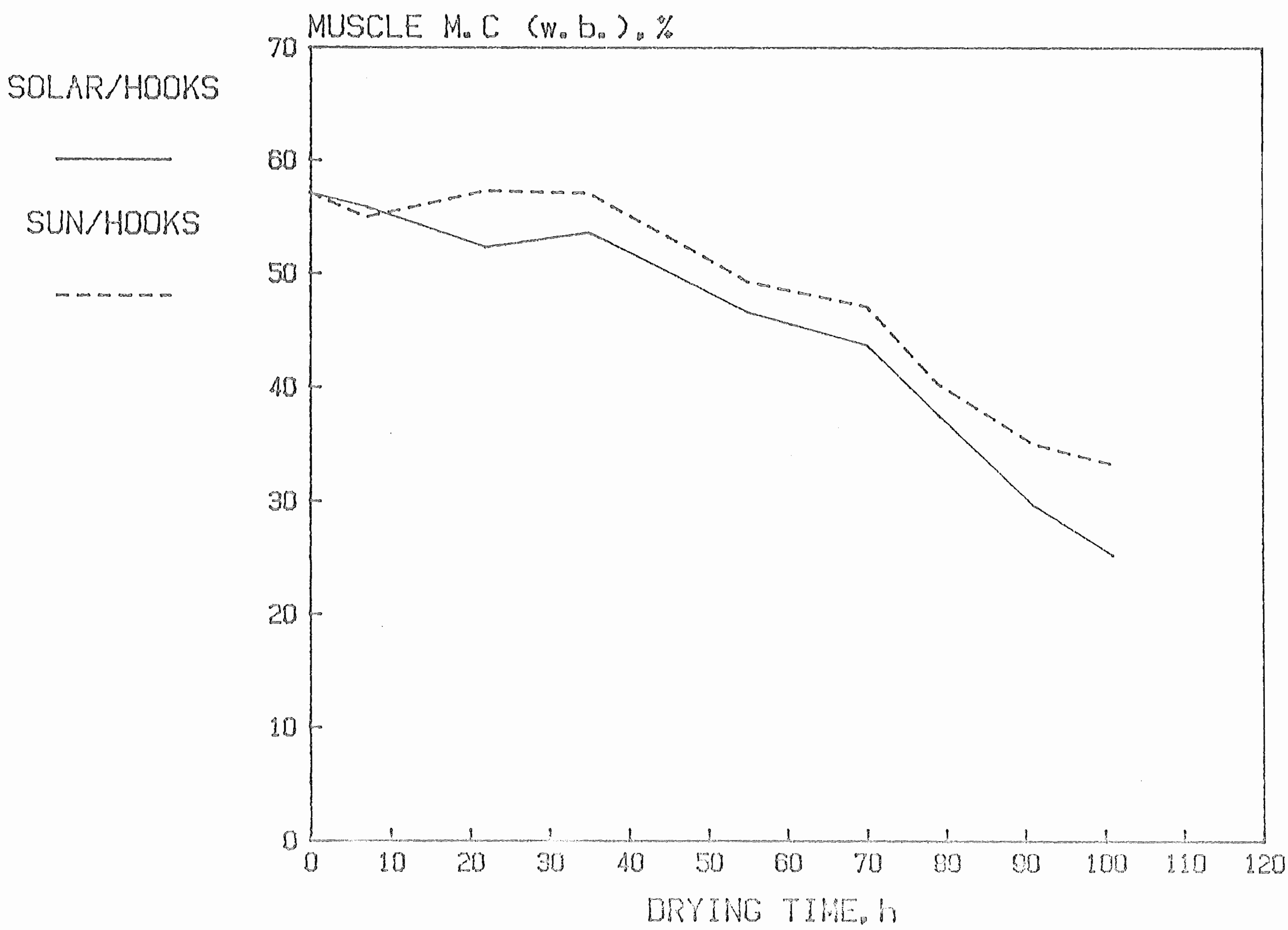


Figure 9

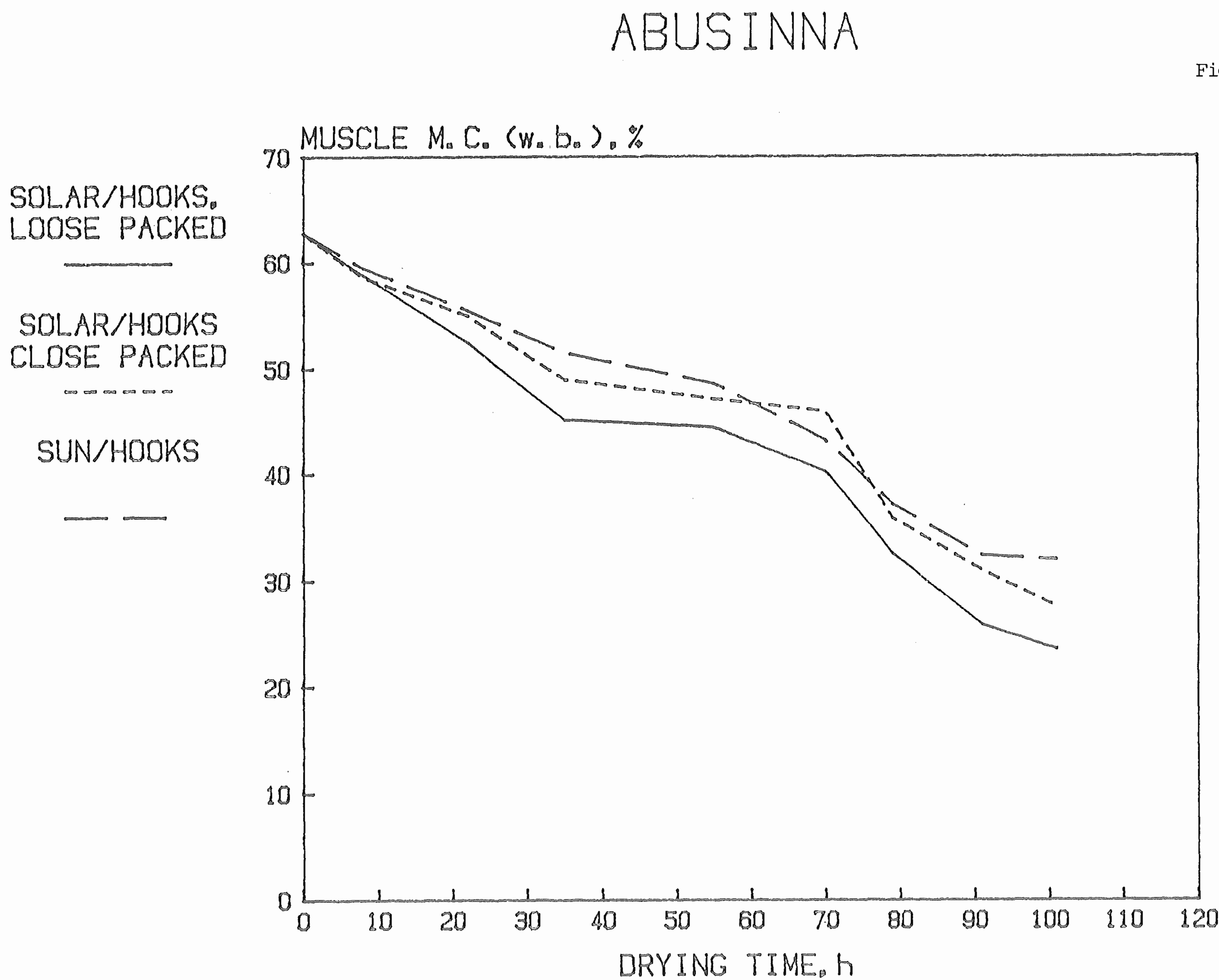
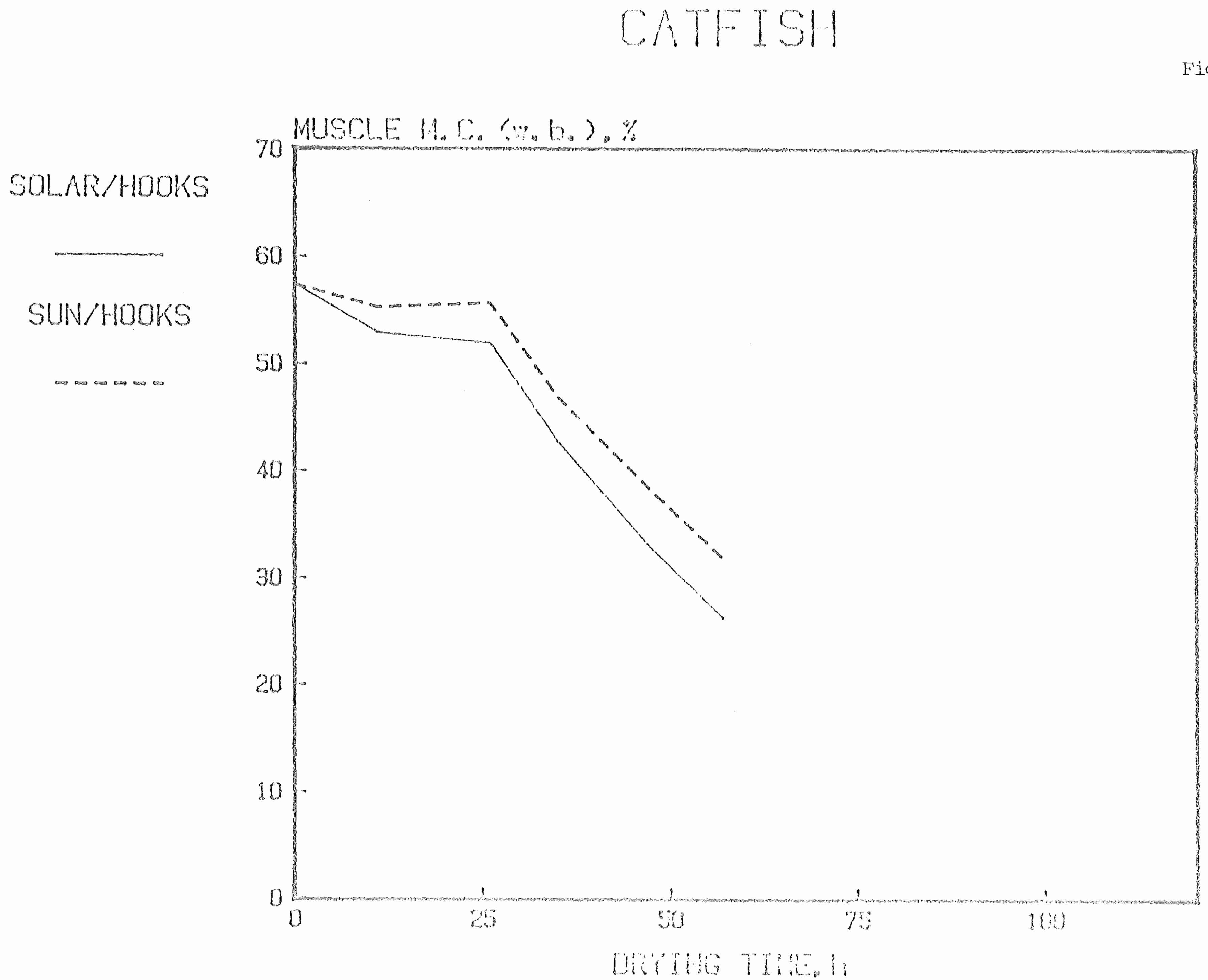
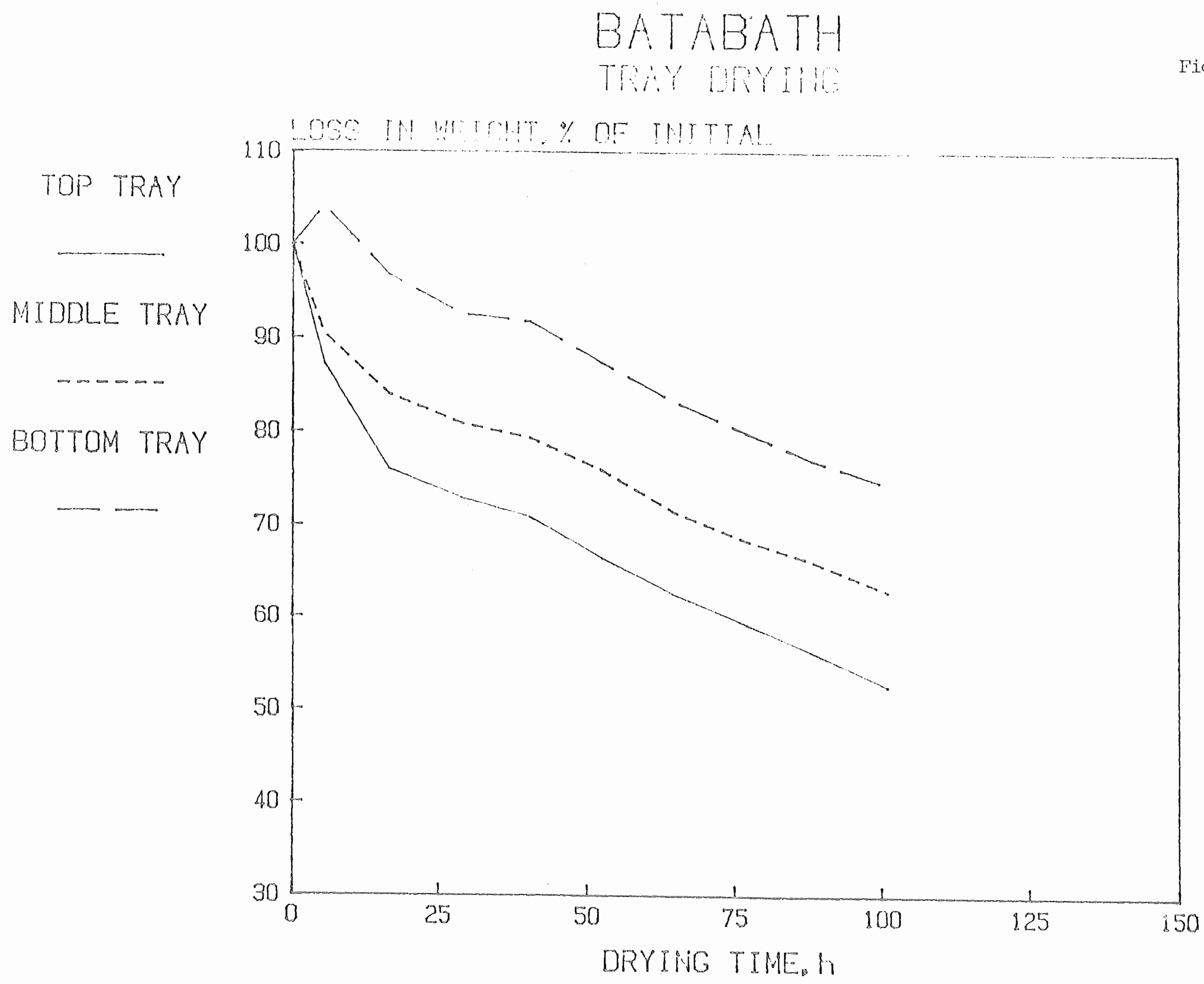

ABUSINNA
MUSCLE M. C. (w. b.), %
DRYING TIME, h
SOLAR/HOOKS, LOOSE PACKED
SOLAR/HOOKS CLOSE PACKED
SUN/HOOKS
0
10
20
30
40
50
60
70
80
90
100
110
120

Figure 10



CATFISH
MUSCLE M.C. (w.b.), %
SOLAR/HOOKS
SUN/HOOKS
70
60
50
40
30
20
10
0
0
25
50
75
100
DRYING TIME, h

Figure 11


BATABATH
TRAY DRYING
LOSS IN WEIGHT, % OF INITIAL
TOP TRAY
MIDDLE TRAY
BOTTOM TRAY
110
100
90
80
70
60
50
40
30
0
25
50
75
100
125
150
DRYING TIME, h