ADAPTATION OF SOLAR TENT DRYER FOR FISH PRESERVATION: IMPLICATIONS FOR FOREST RESOURCES CONSERVATION AROUND KAINJI LAKE, NIGERIA

BY

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SUBMITTED TO THE

POSTGRADUATE SCHOOL
FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA
IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF DOCTOR OF PHILOSOPHY (Ph.D) IN GEOGRAPHY
IN THE DEPARTMENT OF GEOGRAPHY

JULY, 2004.

DECLARATION

I, Julius O. Olokor (Ph.D/SSSE/97/157) hereby declare that this thesis titled: "Adaptation of Solar Tent Dryer for Fish Preservation: Implications for Forest Resources Conservation around Kainji Lake, Nigeria", is an original work carried out by me for the award of a Doctor of Philosophy (Ph.D) in Geography, in the Department of Geography, School of Science and Science Education, Federal University of Technology, Minna, Niger State, Nigeria.

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CERTIFICATION

This is to certify that this thesis titled: "Adaptation of Solar Tent Dryer for Fish Preservation: Implications for Forest Resources Conservation around Kainji Lake, Nigeria" is an original scientific study carried out by J.O. Olokor (Ph.D/SSSE/97/157) under the supervision of Professor D.O. Adefolalu.

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ACKNOWLEDGEMENT

I wish to thank my Supervisor, Professor D.O. Adefolalu for his fatherly understanding and patience that saw this work through. My thanks also go to Dr. G.N. Nsofor, Dr. (Mrs.) Odafen, Professor J.M. Baba and other lecturers of my department for their support. Special thanks to Dr. M.T. Usman, my Head of Department. He is kind, humble and far seeing.

I am grateful to the National Institute for Freshwater Fisheries Research, New Bussa, for sponsoring this work. The same thanks goes to the following organizations for part financial support: The then Nigerian Agricultural Research Project (NARP), under the Federal Ministry of Agriculture and Natural Resources and, the Nigerian-German (GTZ) Kainji Lake Fisheries Promotion Project, New Bussa.

I thank the entire scientists of my Research Institute that have contributed in one way or another to this work. Special thanks to the technical staff that travelled across the country with me to collect the field data used for this work.

My gratitude goes to the numerous fish processors at Gbajibo (Jebba Lake) and those in villages around Kainji Lake for welcoming my team at all times during our trials and transfer of the solar tent technology. I thank them, for their numerous criticisms and suggestions in the development of the solar dryer.

My appreciation goes to the institutions that collaborated with my institute and me during field trials and during the development of the solar dryer. These include: The University of Jos, the College of Education Warri, the Federal College of Freshwater Fisheries Technology, Baga and the Federal College of Forestry Jos. Many thanks also to members of the Aquatic Vegetation Project (under the Ecological Funds of the Presidency) who joined in numerous navigation of the Kainji Lake and survey of its basin to collect ground truth data on vegetation.

Finally, I wish to express my sincere thanks to all those members of staff and management of the Federal University of Technology, Mina who supported this work one way or the other.

ABSTRACT

This study considers the exploitation of solar energy for fish preservation as an alternative to the use of fuel energy for the purpose. It is observed that the huge annual catch of fish from Kainji Lake requires a lot of energy for preservation. Such energy had up till the time of this study been supplied by fuel wood. Not less than 11 species of wood types were involved in fish smoking in the area. This situation has led to serious deforestation in the area.

The study is in two parts. The first part was the study of fuel wood for smoking and the second part was the introduction of solar dryers on an experimental basis. In the case of inventory of wood energy, 76 processors in four fishing villages were studied and the quantity of wood used and the values of fish dried this way were estimated. The solar dryers were tried across all the eco-zones of Nigeria and data of weight loss, taste and time required were computed for all the eco-zones. The solar dryer used, was designed by this researcher to specifications described in this thesis. Suffice here to state that it is an improvement over an earlier design used in Bangladesh in 1977. The comparison between the new design and the old one reveal that the new design performed better. Conditions for fish drying such as temperature and relative humidity were better in the new design. Temperature was 4.6°C higher and relative humidity 8.5% lower in the new dryer compared to the old type.

The results of the study on wood energy show that the average fish processor around Kainji Lake consumes 16.41kg of fuel wood per day or 7.5m^3 of forest wood compared to 0.46m^3 estimated for developing countries by earlier studies.

Satellite image analyses between 1979 and 1999 revealed that forestland decreased from 3,393.8km^2 in 1976/1978 to 1,978.2km^2 in 1993/1995. This is a total forest reduction of 1,415.6km^2 or 41.7%. Undisturbed forests were completely erased over this period. This result indicates an impending deforestation around the basin due to high demand for fuel wood.

Pilot trials across eco-zones of Nigeria show that weight loss of fish dried in the solar dryer decreased from the coastal parts of Nigeria northwards according to latitude. At Warri (Latitude 5^o.30), fresh fish lost only 204 gm or 27.6% in 36 hours compared to Baga (Latitude 13^o.1) where fresh fish lost 514.3gm or 63% over the same time period. Analyses show a strong correlation (r = +0.96) between weight loss and latitude.

Laboratory analyses show that fish products from the developed solar tent were more nutritious and healthy for consumption than those dried in the open sun (fish processors practice). There was a significant difference (P<0.05) at 5% significant level between both fishes. Solar dried fish recorded 43.3cfu/gm of microbes compared to 132.0 cfu/gm for traditional sun dried fish and 64.3 cfu/gm for fresh fish. Water content was lowest for solar dried fish (10.60%) compared to 22.26% for sun-dried fish and 78.96% for fresh fish; percentage protein was highest in solar dried fish (82.14%) compared to 62.3% for sun-dried fish and 21.74% fresh fish.

It is concluded, that the new solar dryer, if adopted, would save the forest from destruction, produce better preserved fish and one that is more palatable too. Thus, the new solar dryer is an appropriate substitute for fuel wood in fish processing for all eco-zones of Nigeria. It is recommended, among other things that, effort should be made by government and the people to produce and adopt the new solar dryer for the preservation of fish in Nigeria.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the study

Renewable energy is a term used to designate non-conventional energy sources such as wind, biomass, hydro and solar energy. In Nigeria, these resources are abundant and are often under exploited (Sambo, 1992). The country is also blessed with primary energy resources such as coal and oil but it has become very obvious that these energy sources pollute the environment and contribute to global warming.

The primary source of energy for the Earth's atmosphere is from the Sun. From time immemorial man has made use of this source of energy to preserve his food. According to Ekechukwu (1999), the earth receives only about one-half of one-billionth of total radiation from the sun and this energy is incident on the earth at the rate of $2.0x10^{15}$ $KWhm^2/day$. Its intensity varies with location, season, day of the month, cloud cover at a point in time, time of the day etc.

Nigeria lies in the tropics where solar radiation is abundant all year round. It is well distributed across the country with total annual average ranging from about $3.5KWhm^2/day$ in the coastal latitude to about $7.05KWhm^2/day$ at the far northern parts (Udo and Aro, 1999). In fact it is believed that Nigeria alone, with an area of $9.24x10^5$ Km^2 on a daily basis receives an average insolation estimated at 5.39×10^{11} KW/day, an energy requirement higher than the annual average used in the country today (Ajisegiri, 2001).

Solar energy can be utilized either as direct thermal energy or through photovoltaic processes. Thermal applications make use of direct heat from the sun while photovoltaic systems utilize the energy from the sun through the use of solar cell by production of photons and phonons that could be tapped as electricity directly. Through this, electricity generation for heating and lighting, water pumping, power for refrigeration, telecommunication etc. can be achieved. Thermal energy conversion is applied for cooking, distillation, water heating and the drying of food items such as crops or fish, which is the focus of this research.

1.2 Statement of Problem

1.2.1 Fish Production and Preservation in Kainji Lake Basin

Kainji Lake is the largest man made Lake in Nigeria. In the year 2001 alone, the lake yielded 13,361 metric tonnes of fish (KLFPP, 2002). The huge annual catches from the lake since 1969 (see table 1.1) require continual and adequate processing to preserve the catch, hence avoid spoilage.

Table1.1 Annual Fish Yield of Lake Kainji 1969 to 2001

Year	Yield (MT)	Year	Yield (MT)
1969	17,000	1977	45,00
1970	28,000	1995	32,478
1971	11,037	1996	38,246
1972	10,905	1997	28,753
1973	7,320	1998	28,851
1974	6,093	1999	16,351
1975	6,000	2000	13,375
1976	5,800	2001	13,361

Source: KLFPP 2002

Freezing, salting, smoking and other forms of drying, can preserve fish. Sun drying is one way by which local fishermen preserve their fish around Kainji Lake. Traditional methods of sun drying involve spreading fresh fish on the ground, mats or grass to dry. Since fish is an extremely perishable food item, when dried using this local method it often go bad during the process because the prevailing ambient conditions of relative humidity and temperature favourable for efficient drying is not attained (Doe, 2002). Spoilage of locally sun-dried fish also results from insect pest infestation such as flies. Flies such as blowflies have been observed to lay their eggs on fish during the drying process because they are exposed. Fish spoilage resulting from insect infestation alone is put at 20% (Eyo, 2001). Traditionally sun dried fish also contains dust, sand and stones due to the way they are processed. These short comings, coupled with foul smell, poor taste and hygiene resulting from poor drying rates have made the product to command lower prices compared to their imported counterpart (stock fish)

1.2.2 Deforestation Resulting from Fish Smoking in Kainji Lake Basin

Over the years many fishermen have migrated to Kainji Lake due to its yield potential. In the year 2000 there were 5,677 fishermen around the lake (KLFPP, 2000). The daily catches of these fishermen require one form of processing or another for preservation. The most common form of fish preservation around the lake is smoking with fuel wood (Eyo, 1999). Fuel wood is estimated to form up to 90% of energy consumption in rural areas such as fishing villages around Kainji Lake (FAO, 1985). This is an estimated consumption of 0.45m^3 of forest wood per person annually. The need for fuel wood to smoke daily fish catch from the lake holds implications for the forests around the lake basin. The situation is more complicated because over half of the forests around the lake basin form parts of the Kainji Lake National Park. This makes the pressure on available forests more imminent. Deforestation is the possible outcome of an area like the Kainji Basin, which has huge annual fish catches that require daily smoking with fuel wood. The forest reserve is also likely to be encroached upon, while desertification and erosion could result from forest deforestation.

Fuel wood consumption as part of the burning of fossil fuel has serious implications for global warming through the emission of carbon dioxide and deforestation (Watson *et al.*, 1990).

1.2.3 Fuel wood consumption and CO_2 Emission

Carbon dioxide is a naturally occurring atmospheric constituent that is cycled between reservoirs in the ocean, the atmosphere, and the land. According to Hartmann (1994), about 5 Gt C year $^{-1}$ (gigatons of carbon per year) are currently released into the atmosphere from fossil fuel combustion, and roughly another 2 Gt C year $^{-1}$ are released by deforestation. Hartmann (1994), noted that even though the ocean takes up some of this excess carbon, the atmospheric content is currently increasing by about 3 Gt C year^{-1} or about 0.5% year^{-1} and estimated that, 25% increase in atmospheric CO_2 during the industrial era is associated primarily with fossil fuel burning.

Watson *et al.* (1990) have shown that the recent rapid increase in atmospheric CO_2 concentration follows very closely the increasing trends of fossil fuel combustion. They estimated that during the period 1850 –1986, 195+20 GT C were released by fossil fuel burning and 117$\pm$35 Gt C by deforestation and changes in land use, for a total airborne carbon production of 312+55Gt C3. Thus about 41$\pm$6% of this carbon has remained in the atmosphere.

Solar energy is known to be the safest form of energy from the environmental point of view (Ajisegiri, 2001). Its utilization for fish preservation around Kainji Lake can help reduce burning of wood and carbon emission from the area.

1.3 Aim and Objectives of Study

The main aim of this study is to construct and test a simple, cheap, efficient and easily adoptable solar dryer which depends only on solar energy to process and preserve fish as an alternative to smoked fish produce, so as to conserve forest resources around Lake Kainji.

The specific objectives to achieve the main aim are:

a. To estimate the amount of fuel wood used by fish smokers around Lake Kainji and to show the possible contribution of this practice to deforestation in the area.
b. To construct a cheap, simple and easily adoptable solar dryer using meteorological and weight loss parameters within and outside the solar dryer.
c. To use the developed technology to preserve fish and to compare the quality of this fish to traditionally sun-dried fish in terms of hygiene, nutrient quality and palatability.
4. To carry out pilot trials of the designed solar dryer across five different eco-zones of Nigeria, as an assessment of its performance across the country.

1.4 Justification

1.4.1. The need for Fish Preservation Around Kainji Lake

Fish is a richer source of protein compared to meat or eggs. But it is an extremely perishable foodstuff. Spoilage occurs as a result of the action of enzymes (autolysis) and bacteria present in the fish and also oxidation of the fat, which causes rancidity (Anon, 1998). At the high temperature prevalent in the tropics, bacterial and enzymes action is enhanced, thus fish invariably becomes putrid within few hours after capture unless they are preserved in some way to reduce this microbial and autolytic activity.

Around Kainji Lake, fishermen preserve their fish either by smoking with fuel wood, by salting or by drying in the sun. Preservation by freezing is not common in the villages, since most of them are without electricity.

Traditional sun drying of fish involves direct exposure of fish to sunlight by spreading them on concrete floors, platforms or on the ground, to get them dried. This technique is unreliable due to cloud cover, rains, high humidity, insect damage and contamination from air-borne dust. The result is the associated huge losses in quality and quantity of the fish products resulting from poor drying (Danshehu *et al.*, 1995).

The economic conditions of the rural fish processors calls for improvement on the traditional method of drying from the popular open air to enclosed drying such as solar dryers. A cleaner product is obtained when solar dryers are used, since the fish do not come into contact with the ground, domestic animals and pests (such as mice, rats and crawling insects) that contaminate or consume them. The products are also protected from rain by the covering provided by the dryers, such as polyethylene or glass materials. The solar dryers ensure faster drying rates, allow proper air circulation from beneath and around the fish products and enhance the final quality (Doe, 1998).

Thus in the search for improved drying techniques, the use of solar dryers has been introduced in many parts of the world as an alternative to traditional sun drying. Solar dryers generate higher sensible heat than sun-drying process. As a result the products of the dryer come out with better quality and consistencies when compared to sun-dried products because the dryers have higher evaporative capabilities.

Ajisegiri, (2001) gave the following as some of the advantages of using solar dryers over sun-drying:

a. Solar dryers generate higher temperature which result in lower moisture content of dried products and thus better quality compared to sun-dried products.

b. Because of the rapid loss of moisture of products inside solar dryers, there is the tendency to have higher batch outputs.

c. Due to the higher drying rates of solar dryers, bed depth and economy of space can be increased.

Other advantages as given by Danshehu *et al.* (1995) are:

a. Solar dryer requires a smaller area of land to dry similar amounts of fish that would have traditionally been dried in the open-air sun drying.
b. Flexibility in applications makes solar dryers to be used for the drying of a variety of different food products for human and animals consumption
c. The relatively low running costs coupled with the above mentioned advantages enable solar drying systems to compete economically with the common traditional open-air sun drying especially if the designs are kept simple and cheap.
d. The use of solar dryers unlike fish smoking is environmentally friendly because they do not emit any form of green house gas or substance dangerous to the ecosystem.

There lies the justification of this study, which is funded by the Nigeria-German Kainji Lake Fisheries Promotion Project

1.5 The study area

The study is the Kainji Lake Basin (Appendix C, Figure C2). Areas designated as belonging to the lake basin are those adjoining the lake, from where runoffs and rivers empty into the lake. These include catchments such as: Yelwa-Melanville, Melando and Kuruwasa-Yelwa catchments. The total area of the catchments is $1.6x10^6$ km^2 (NEDECO and Balfour Beatty, 1961). The study area lies between Longitude 3° 26' and 6° 05'E and Latitude 9° 15' and 12° 08'N.

1.5.1 The Kainji Lake

Kainji Lake (Figure 1.1) lies between Latitude 9° 50' and Latitude 10°55'N and between Longitude 4° 23' and Longitude 4° 45'E. Construction work on the Kainji dam began in March 1964 and was completed in December 1968. The lake that was formed inundated most parts of the Kainji Island on which the embankment was built, except the southern tip. Kainji Island was about 4.02 km long and was within the River Niger on latitude 9° 40'N.

Impoundment of the Kainji Reservoir started on the 2nd of August 1968. The lake water level rose up steadily to 140.2m (Above mean sea Level) on the 19th of October, a period of 78 days. The lake covers a total area of 1250km^2. It has a maximum depth of 54.9m and maximum width of 24km. It is 136.9 km long. The lake water has a surface temperature of 23 – 31 ° C (Niger Dam Authority, 1973).

Before impoundment, Foge Island was at the center of the lake. The Island was cleared of its vegetation to encourage net fishing on the lake to be formed, while part of the vegetation was left to provide shelter and feeding grounds for fish.

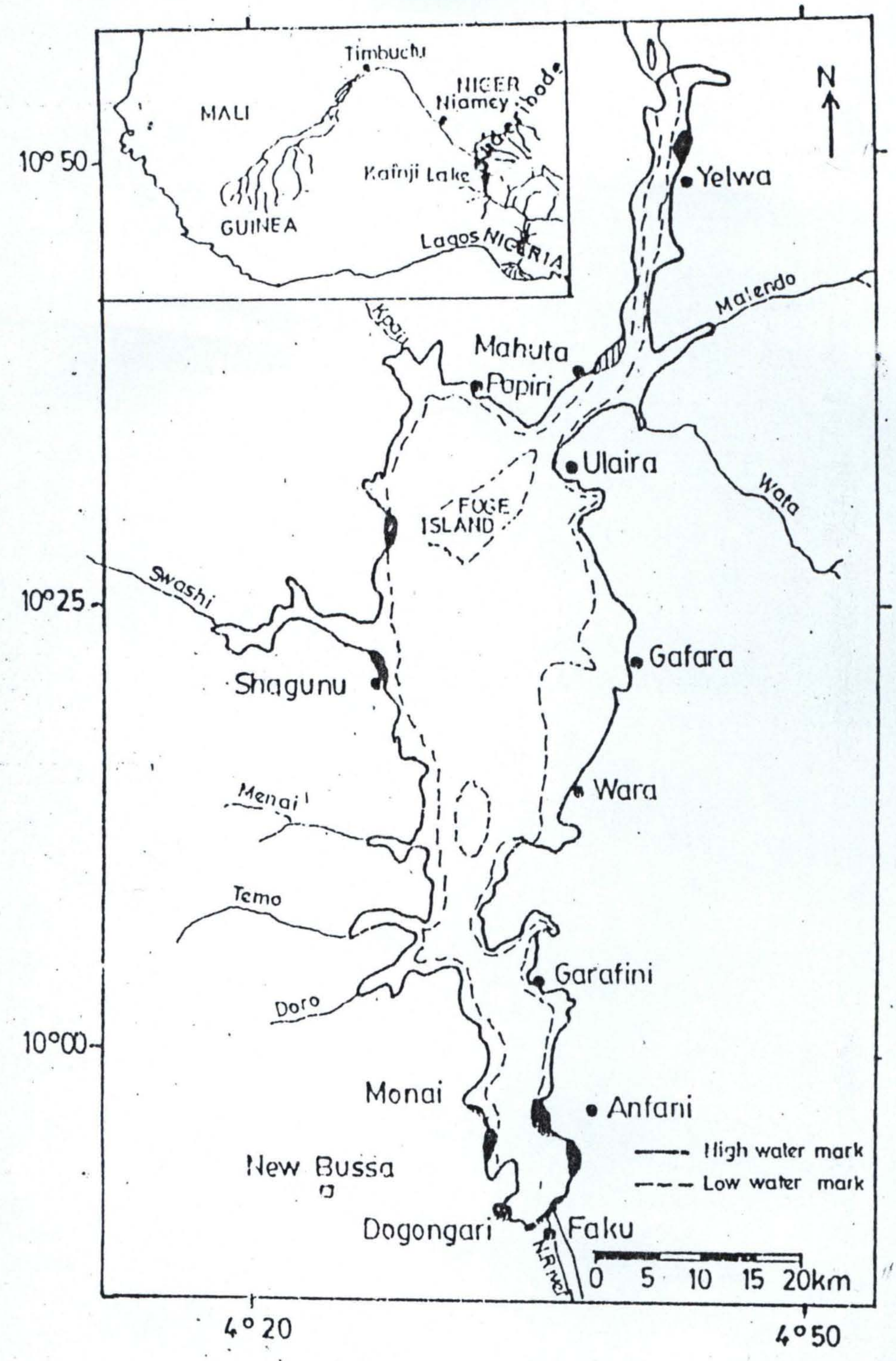


Fig. 1. Map of Kainji Lake. Inset shows the River Niger basin and its tributaries.

1.5.2 Hydrology and Drainage of the Kainji Lake and its Basin

Lake Kainji gets its water from two sources: The Niger with its head waters in Guinea, and local rivers around the lake basin, which flow directly into the lake or into the Niger first before entering the lake.

The Niger takes its rise from the Fouta Djallon highlands at an altitude of 1000m above sea level, flows in a northeasterly direction and then southeast into the Atlantic Ocean through Nigeria, a distance of 4,183km (Niger Dam Authority, 1973). Water originating from the source area of the Niger and its catchments travel a distance of 2,737km to reach the lake 6 months later (NEDECO, 1961). On its way, the water drains the swamp of Timbuktu where it looses 65 percent of its water to evaporation and infiltration, (NEDECO, 1961). Having deposited its silt in these swampy areas the water becomes relatively clean and appears black at a distant, on its arrival at the lake, hence it is called the "black flood". This flood occurs between December and March yearly with a discharge of 1,700 and 2,000 cubic meters per second and then recedes to between 200 and 400 cubic meters per second in May and August when the "white flood" takes over (Adeniji and Mbagwu, 1998).

The "white flood" which originates from local runoffs around the catchments of Kainji Lake occurs from August to November annually. It carries a lot of silt and mud giving it the milky look from which it gets its name. The flood reaches its peak about September 30th and is much higher than that of the "black flood".

Its peak discharge is about 4,000 cubic meters per second and levels down to 1,500 cubic meters per second in November when the "black flood" takes over again. The Niger leaves the dam on its way to the ocean carrying 5,050,000 tonnes of suspended silt per year (Adeniji and Mbagwu, 1998).

Much work has not been done on the eastern section of the lake except for NEDECO and Balfour Beatty (1961). Valette (1973) did a soil survey of the southern eastern part of the lake. His report showed that the behaviour of the rivers in this part of the basin depends largely on the geomorphology. Areas underlain by granite have closely spaced systems or streams. While the Nupe sandstone plains have widely spaced dendritic drainage patterns. The whole of this section is drained by river Kontagora into the Niger below the dam, while River Malendo drains the northern eastern section directly into the lake. Other rivers in the eastern section are Wala (northeast) and Wo at east central part.

More rivers drain into the lake on the western part. They are Kpan (Northwest), Swashi (at the west central part, draining into the lake with a well defined estuary), Timo, Doro and Menai, all with small estuaries.

Child (1974) carried out an ecological survey of the Borgu Game Reserve for FAO. His report showed rivers and streams draining this region of the lake area. These rivers dry up in the dry season except Oli, Menai, Timo, Uffa and Nanu. However, the major river, Oli with peak discharge of 752 m3/sec. in

1959/1960 drains the majority of the area downstream the Kainji dam. Child (1974) reported that when the lake reaches its highest watermark at the driest time of the year, it gives maximum flood back to Doro, Timo and Menai rivers at such times.

The most detailed hydrological survey of the Kainji lake area done till date is that of NEDECO and Balfour Beatty (1961). The report divided the entire area around the lake from Niamey to Jebba into twelve catchment areas. Those whose water enters the lake are: Melanville – Niamey, Sokoto, Yelwa – Melanville, Melando and Kurwasa – Yelwa catchments areas. These are the sources of the local white flood. The survey undertook discharge measurements in all the major rivers of the area and drew their hydrographs. Sediment measurements were also taken and a lot of meteorological data collected. The results of the study showed that in the whole year of 1959 (a wet year), the Niger carried past Jebba a total of 4.6 million tonnes of silt.

1.5.3 Soil and land use.

Considerable work has been done on the soils of the lake area. These include Pullan and de Leeuw (1964) and Klinkerberg (1965). A brief report was given in child (1974) and MINCO (1977). NEDECO and Balfour Beatty (1961) provided the basic geological maps, which many of these studies were based on.

Klinkerberg (1965) in a very detailed report noted that soil types of the area vary according to underlying rock types. He categorized the geology of the area as: Metasediments, Gneiss, Granite and Nupe sandstone.

The area in and around the lake is characterized by undulating topography with the eastern side being flatter than the western side. The relief range between 180m and 300m. The altitude of the entire area is not likely to affect fish drying across the lake basin since the entire terrain is gently undulating and has no contrasting feature.

As observed by Klingerberg (1965), the underlying geology is the key to soils, their distinct characteristics and properties. Nupe sandstone of varying thickness covers the whole of the western bank. Beneath these are primary rocks of schist and gneiss, which belong to the basement complex and are of pre-cambrian age. The Nupe sandstone extending from Shagunu westward over Borgu Game Reserves have deep, red sand or loamy sand and clay loam soil.

Soils over Gneiss are found southward of Shagunu across the Menai River extending up to River Doro. They also occur on the northeastern bank of the lake above Melando River up to Yelwa. Such soils are grey brown or yellow brown loamy sand over grey clay loam with frequent outcrop (Klinkenberg, 1965).

Soils over metasediments are next in extent to the Nupe sandstone. They extend from River Wo up to Malendo River east of the lake, and then to the extreme north of the lake from Agwara northwards. Klinkeberg (1965) describes such soils as yellowish clay loam soils, sometimes with an overlay of reddish brown loam and with high pH (8.0 – 9.7). In general the soils of the area belong to the tropical ferruginous soils. MINCO (1977) analyzed the chemical component of the upland, valley and alluvial soils. Upland soils for instance have low clay content, low carbon denoting, low organic matter and nitrogen, relatively low phosphate and poor cation exchange capacity.

After the formation of the lake, the settlers, who were mostly fishermen and farmers, continued with their traditional occupations. Most of the farming activities around the lake are confined to the upland and to a little extent in the drawdown areas in the northeastern part of the lake. Farming is done at subsistence level with locally forged tools. Occasionally, tractors are utilized to clear the field but harvest is solely by the entire household. The farmers, practice shifting cultivation, spending 3 – 10 years or 10 – 20 years on a farm depending on the population size of that area. The average size of plots is between 3 – 6 acres and a farmer can have a few of such.

The major crops grown are: Guinea corn, millet, rice, maize, cowpeas, pigeon peas, Soya beans and vegetables. Farming is done in the immediate vicinity of the villages. It is done along with keeping a handful of livestock made up of a few goats and poultry. Onions and rice are mostly farmed in the drawdown areas, and it is expected that much of the fertilizers will be washed into lake as runoffs, since peak of farming coincides with that of the rains. The introduction of solar dryers will afford fishermen the added advantage of leaving their fish to dry while they go to the lake, unlike fish smoking that require close supervision.

1.5.4 Vegetation

The study area generally falls into the Guinea savanna zone characterized by tall grasses and short scattered trees, which adapt themselves to the harsh 5-month dry season and frequent bush fires. The trees are deciduous in nature, shedding their leaves in the dry season to reduce water loss through transpiration. Some of them are deep rooted (e.g. Acacias). Grasses grow up to 4m tall and the entire landscape appears green and fresh in the rainy season but quickly turn yellowish brown in the dry season.

The vegetation can be generally classed into two groups according to Child (1974). These are:

a. Savanna woodlands: Which comprise *Burkea africana – Detarium microcarpum* woodland, *Diospyros mespiliforms* and *isoberlinia doka* savanna woodland

b. Riparian Forest and woodlands. This type includes vegetation of watercourses. They develop into denser forest unlike the first group and remain relatively green throughout the year because of access to water. Some of the trees found in this group are: *Daniellia Oiveri, Ficus species, Parkia clappertoniana* etc. Most of these trees are fell for fuel wood to smoke fish.

The landscape of the study area consists of trees interspersed with grasses, which constitute the dominant vegetation and occur widely over the entire area.

1.6 Scope and Limitations

This study cuts across several disciplines such as fisheries, physics, forestry, climatology and nutrition. But for the purpose of this project, emphasis was placed on the relevant geographical principles within these disciplines leading to the attainment of the set aims and objectives due to time and material constraint.

1.8 Structure of Thesis

This study has been organized into an introductory part, experimental part and data analyses and presentation part. The introductory part comprise chapters one and two which focused on the study area, fish production in Kainji Lake, fuel wood consumption, CO_2 emission and solar dryers. Experimental methods were discussed in chapter three while chapter four was an analyses of experimental data. Chapter four also shows the results of the study while chapter five summarises findings of the study and makes recommendation for further research.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Fish Drying

Ajisegiri (2001) defined drying as a process of simultaneous heat and moisture transfer. Moisture is evaporated from the product being dried by the heat. The transportation of both heat and moisture in the product is usually done by air. Fish like any agricultural product is dried by the same principle. The drying of fish in the open sun has been in practice since the early days of civilization. But modern methods of drying are gradually becoming common. These involve the use of simple solar and mechanical dryers.

2.1.1 The Theory of Fish Drying

The basic principle behind fish drying is to lower the moisture content of fish to such a level that micro-organisms are rendered inactive. The moisture content (m.c) is the quantity of moisture present in the fish per unit weight or volume of either fresh or dried fish.

If moisture content of fresh fish is reduced during drying to around 25%, bacteria cannot survive and autolytic activity will be greatly reduced. But to prevent mould growth, the moisture content must be reduced to 15% (Trim and Curran, 1983).

The heat required for sun drying occurs in form of sensible heat derived from solar radiation, while the differential water vapour pressure of air as against that of fish result from ambient relative humidity and wind speed. While solar energy helps to destroy the microorganisms, dry air helps to extract moisture from the fish thereby making it unsuitable for their growth.

2.1.2 Stages of Fish Drying

According to Eyo (2001), there are two stages of fish drying. These are:- removal of moisture from the surface of fish, referred to as constant rate drying and removal of moisture from within the fish, referred to as falling rate

2.1.2.1 Constant rate drying

Ajisegiri (2001) explained that drying involves the diffusion of water into the relatively stagnant mass of air around the product (or fish in this case) from where it is lost to the environment. During constant drying rate, there is a greater external resistance to vapour removal than the internal resistance to moisture movement up to the surface.

At this stage, three properties determine the rate of drying. They are:

a. The humidity of the air
b. The velocity of the air
c. The temperature of the air.

A typical solar dryer helps to facilitate these three properties to ensure drying of fish or other agricultural products. Hence data collection on these variables within and outside the adapted solar dryer is crucial for this study, as this will help to determine the performance of the dryer. Other factors which affect drying of fish, according to Eyo (2001) are: size of fish, fat content and salt content.

2.1.2.2 Falling Rate Drying Stage

The falling rate period takes off from the point where the constant rate-drying period ends. This point is referred to as critical moisture content. Beyond this point, the surface area of the product is no longer completely covered by a thin layer of water and so the internal resistance to transfer of moisture is more than the external resistance to evaporation. Thus more moisture is lost at the surface than can be replenished; hence it is called falling rate period (Ajisegiri, 2001)

2.2.0 Classification of Solar Dryers.

Many forms of solar dryers for use with agricultural products have been developed in many parts of the world but only a few have been used specifically with fish. Doe *et al.* (1977) and Trim and Curran (1983) are some examples of studies where solar dryers were used specifically to dry fish.

Trim and Curran (1983) classified solar dryers into two major groups on the basis of the mode of airflow through the dryer. These are:

a. Forced convection: Dryers that use forced convection require a source of motive power, usually electricity, to propel the fan that provides the air. In many rural communities motive power from any source is either unavailable or, at best, unreliable and expensive, making the introduction of these kinds of dryers not a viable option for such communities.

b. Natural convection: These kinds of dryers rely solely on natural mode of airflow to dry fish. Natural-convection dryers are most practicable in communities where motive energy is not easy to come by. Some of the solar dryers in this group are discussed below:

2.3.0 Some natural-convection dryers that can be used to dry fish

2.3.1. The Solar tent dryer.

The solar tent dryer was developed by Doe and others, (Doe *et al.,* 1977 and Doe, 1979) and initially tested in Bangladesh with fish. Tropical Product Institute has tested this dryer in Africa, SE Asia and Latin America for production of various dried fish products and it has shown considerable promise. During the course of this study this dryer was modified and tried in Nigeria. A sketch of the dryer is shown in figure 2.1.

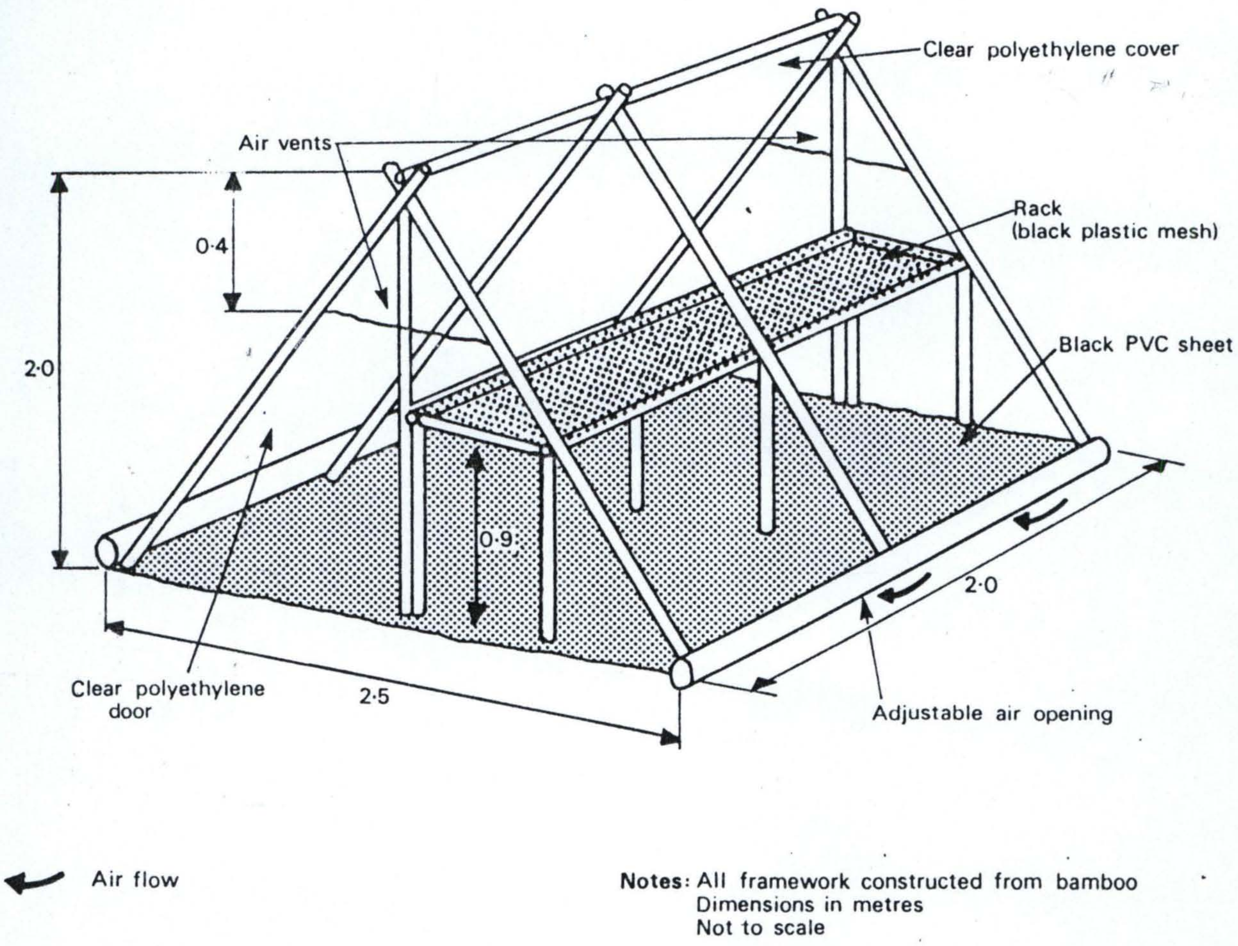


Figure 2.1: Schematic Diagram of Doe (1977) Solar Tent Dryer
Source: Trim and Curran (1983)

The dryer consists of a transparent polyethylene sheet worn over a bamboo tent. The polyethylene is transparent to incoming solar radiation but opaque to out going terrestrial radiation. As such there is a build up of heat within the dryer causing the air within the dryer to be heated. Openings at the base of both sides of the dryer allow cooler air to be drawn in, and vents in the apex at both ends allow the air to escape. Some control of the internal temperature, and flow of air through the dryer, can be maintained by adjusting the height of the side openings.

Trim and Curan (1983) tried this dryer at Ecuador successfully with fish. They constructed it with a bamboo framework and plastic sheet. Black polyvinyl chloride (PVC) was used for the base of the tent and clear ultra-violet-resistant polyethylene for the sides and ends. The drying rack inside the tent was constructed using black plastic mesh fixed on bamboo frame and legs. Access to the rack was through a movable plastic flap forming half of one end of the tent. The flap could be closed and fastened when not in use. They estimated the construction time for the tent dryer to be about 6 man-hours.

2.3.2 SCD (Separate Chamber Dryer) dryer

This dryer was developed by Exell and others (Exell and Kornsakoo, 1978, Exell *et al.*, 1979; exell, 1980) at the Asian Institute of Technology (AIT) in Thailand. It differs principally from the solar tent dryer used for this study because

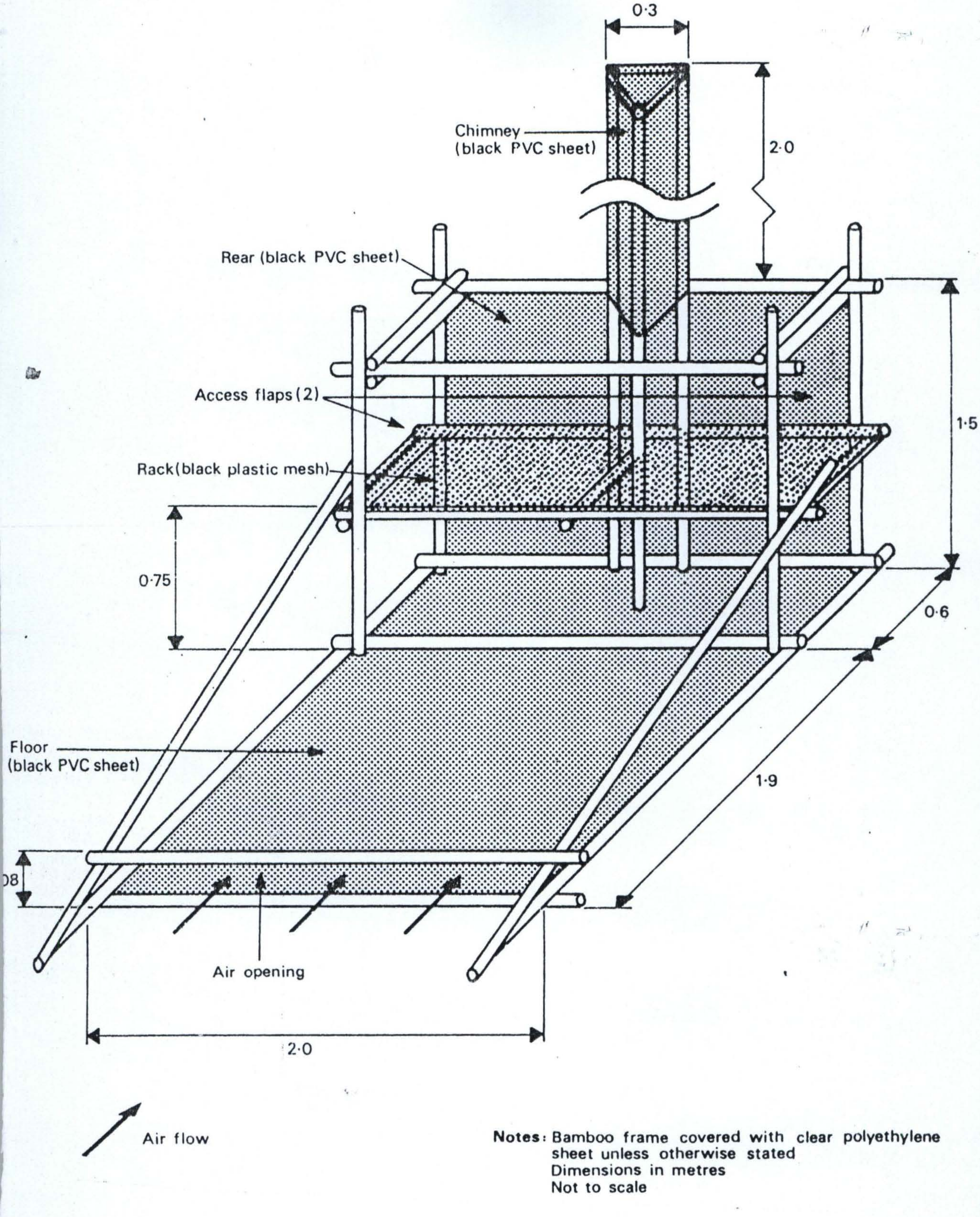


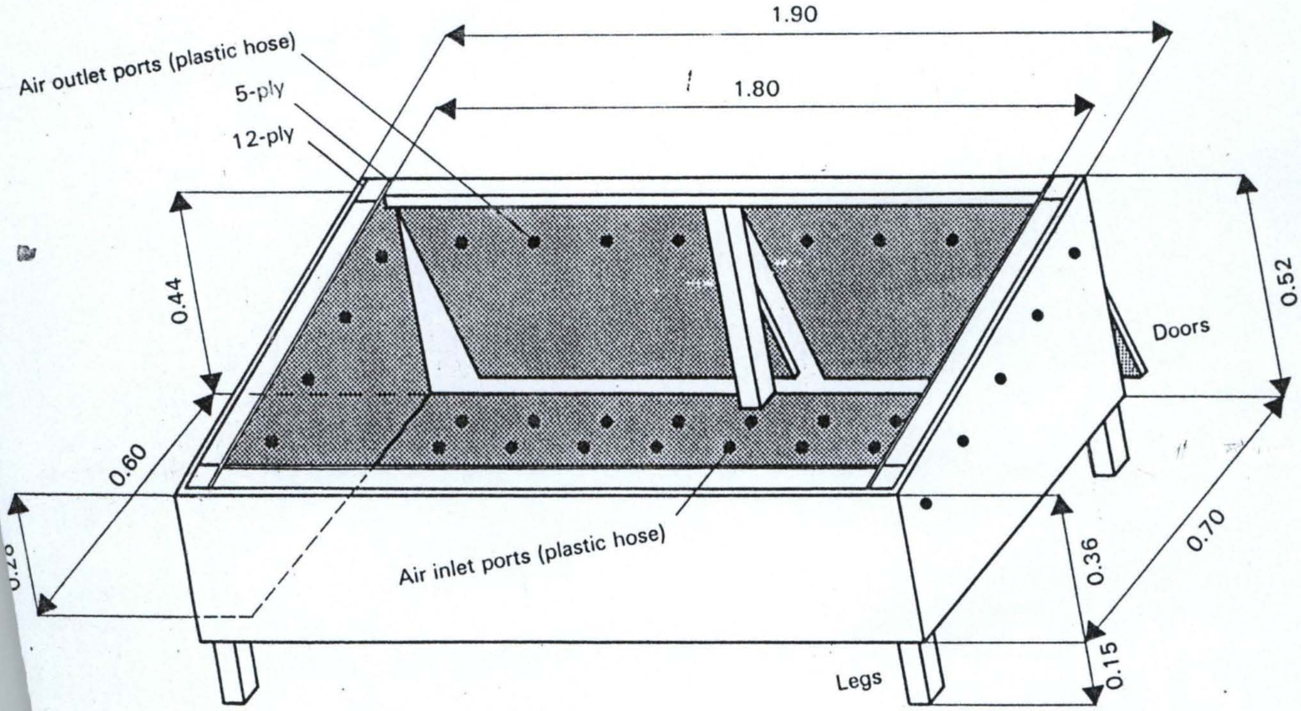
Figure 2.2: Schematic Diagram of SCD Solar Dryer
Source: Trim and Curran (1983)

the solar collector and the drying chamber are distinctly separate as shown in figure 2.2. Originally the inventors of the dryer developed it for use with paddy. The solar collector of this dryer is made of a black PVC base with an inclined transparent plastic cover with a narrow opening across the full width of the end of the collector. Air is heated during its flow through the collector and passes into the drying chamber before being expelled through the chimney. The function of the extended chimney is to absorb radiant energy, which heats the air within, thereby facilitating the natural convective flow of air through the dryer.

In constructing this dryer, materials identical to those used for the solar tent were used. The base of the collector, the base and back of the drying chamber, and the sides of the chimney were of black PVC, and the collector cover and the top and sides of the drying chamber were of transparent polyethylene. Access to the drying rack was provided by plastic flaps on either side of the drying chamber, which also provides a means of controlling the internal temperature. It took Trim and Curran (1983) about 15 man-hours to construct this dryer.

2.3.3 Solar Cabinet Dryer.

Lawand (1966) and the Brace Research Institute (1973) pioneered the design of this dryer. It is probably the most widely used dryer developed to date that is being utilized for a large number of commodities (Trim and Curran, 1983). Figure 2.3, shows the dryer. It is basically made of a rectangular cabinet with an



Notes: Dryer constructed of plywood on wooden frame
Top of cabinet covered with clear polyethylene sheet
Dimensions in metres
Not to scale

Figure 2.3: Schematic Diagram of Solar Cabinet Dryer
Source: Trim and Curran (1983)

inclined transparent cover. The optimum angle of inclination of the cover is dependent upon the geographical latitude (Brace Research Institute, 1973)

Air inlet ports at the base of the cabinet provide entry of fresh air, which when heated within the cabinet, rises to escape through outlet ports in the upper parts of the front and sides. The potential of the cabinet to absorb insolation is enhanced by darkening all its interior surfaces. It is normally recommended that the front, sides and base be of double walled and the cavity should be filled with materials that serve as good insulation, e.g. sawdust.

The need for solar dryers by rural fishing communities to reduce greenhouse gas emission through the use of fuel wood for fish smoking is further shown in the next section of this chapter. Smoke from fuel wood used for fish smoking has its share of contribution of CO_2 to global levels and climate change. The impacts of global warming resulting from greenhouse gas emission from human activities in particular are discussed below.

2.4. 0 Climate Change resulting from Human Activities

According to Cerling (1991), the greenhouse effect that warms the surface of earth above the normal temperature results because a few minor constituents absorb thermal infrared radiation very efficiently. As a result of human activities, the atmospheric concentrations of some of these natural greenhouse gases are increasing, and entirely new man-made greenhouse gases have been introduced into the atmosphere. Climate change models point to the fact that the increase in the atmospheric greenhouse effect will warm the surface of the Earth. Hartmman (1994) stressed that, when the effects of feedback processes within the climate system are taken into account, it becomes clear that human activities are leading to a global climate change that may produce a mean surface temperature on Earth as warm as any for more than a million years.

2.4.1 Humans and the Greenhouse Effect

The contributions to the global warming from greenhouse gases during the 1980s as given by IPCC (1990) working group shows that Carbon dioxide contributed more than half of the anomalous global warming while chlorofluorocarbons (CFCs) contributed about one-quarter of the total for this period. Carbon dioxide thus will make the most important single contribution to greenhouse gas forcing of global warming, although the contributions from a number of other minor constituents add up to a substantial climate change (IPCC, 1990).

2.4.2 Impacts of Climate Change

In recent times there has been a lot of reference to short-term weather anomalies and slowly developing changes of climate that has triggered severe economic, social and political dislocations. In the 1990s adverse weather in a few regions affected food prices, balance of trade, and human settlements worldwide (Shackley and Deanwood, 2001). Developed and developing countries alike find themselves increasingly vulnerable to "abnormal weather". Furthermore, there is a growing realization that a carbon dioxide-induced climatic change could have much larger impacts than any of these short-term events.

The study of climatic impacts on human activities is a contemporary area of research already. Water resource managers consider climate in their planning while, agronomists use crop models to predict changes in productivity for given changes in temperature, precipitation, and sunlight. Economists have been experimenting with models that attempt to forecast the costs and benefits of a specified climatic change on certain economic sectors; and anthropologists have long been aware of the effects of climate on patterns of migration and settlement (Schumann and Antl, 2002).

2.4.3 Impacts of Climate Change on Human Activities

2.4.3.1 Energy Supply and Demand.

Lovins (1980) is of the view that energy demand in the tropics would probably change a little if global temperatures rose due to an increase in carbon dioxide. According to him, at the middle latitudes, however, there would be a decrease of demand for heating in the winter and an increase in demand for air conditioning in summer, shifting the kind of power from heating fuel to electricity for cooling. The pattern of energy demands may not shift uniformly pole ward, since, the regional changes of temperature and rainfall will be complex. Many forecasts and models have been made about the patterns of temperature changes to be experienced with global warming (Ennet *et al.*, 1998).

2.4.3.2 World Food Production

Direct impact of climate change on global food production has been established by many studies. But significantly important also is the changing climate's effects on the frequency and severity of pests' outbreaks. Agricultural losses due to pests have been put at about 25 percent (Primente, 1978). Temperature increase may make pest control even more difficult than it already is. The same may be true for a variety of plant diseases. As Thompson (1975) has noted 95% of human nutrition is derived from about three crops only: wheat, rice and maize. Any significant impact of disease or pests on these will be very severe.

2.4.3.3 Global Ecology

Temperature, precipitation, soil type, and availability of sunlight, among other variables, determine the kind of biome that will thrive in a given region. The first two are generally the most important. According to Meryer *et al.* (1999), climate scenarios show that a slow climatic change will affect temperature and precipitation, forcing the biomes to shift, as some species in each region die out and others succeed them. They were of the view that this has occurred many times throughout geological history. For example, during the warm Altithermal Period some 5000, years ago the spruce forests of central Canada extended 300 to 400 kilometers further north than they do now. Woodwell (1978) was of the view that at that time the Sahara was not a desert but semiarid grassland that supported grazing animals and nomadic people. According to him, whether ecosystems can adapt successfully to a climatic change will depend on how fast the change occurs. This is because, while the life span of individual trees and other plants is many decades, the response of an entire ecosystem occurs over several plants lifetime.

2.4.3.4 Water Resources

Man depends on a reliable supply of freshwater for survival. A climate change will surely shift patterns of precipitation, and this will directly affect the water resources of every region. Some scenarios show that area with marginal water resources such as in the Midwestern United States and Russia will be the hardest hit if there is a decrease in rainfall (Dickinson 1991; Kaleris *et.al.* 2001). Flohn's (1979) scenario indicates that many developing countries in the semiarid parts of the subtropics are now expected to experience a general increase of precipitation and soil moisture if a climate warming occurs. Changes in precipitation and soil moisture are key elements in food and forest production.

Many of the dams, pumping stations, reservoirs, and river distribution networks around the world such as the Kainji Lake at the time of impoundment may not have been designed with present climatic changes in mind. Kainji Lake which has an expected life span of 1000 years (Niger Dam Authority, 1972) is presently experiencing heavy rains and unprecedented floods. Figure 2.4 show a rising annual rainfall for Kainji Lake Basin between 1969 and 1999. This trend may be due to micro or macro changes in climate around the basin. This makes this study timely since forest removal is a contributing factor for global warming.

2.4.3.5 Fisheries

Up until the early 1970s rivers, lakes, and coastal areas of the world were generally viewed as vast, almost limitless resources of food. As late as the 1960s and early 1970s scientists had reported that fish catches could be greatly increased, and would provide a large supplement to food production on land. However, after 1972, global fish catches declined from their peak of 26.5 million tons to 18.5 million tons in 1973 (FAO, 1973). Adeniji (1977) and Nwoko (1978 and 1991) attributed the crash in the fisheries of Lake Kainji and Chad to the 1972-1973 drought. There has recently been a partial recovery with increasing rainfalls and floods due to global warming

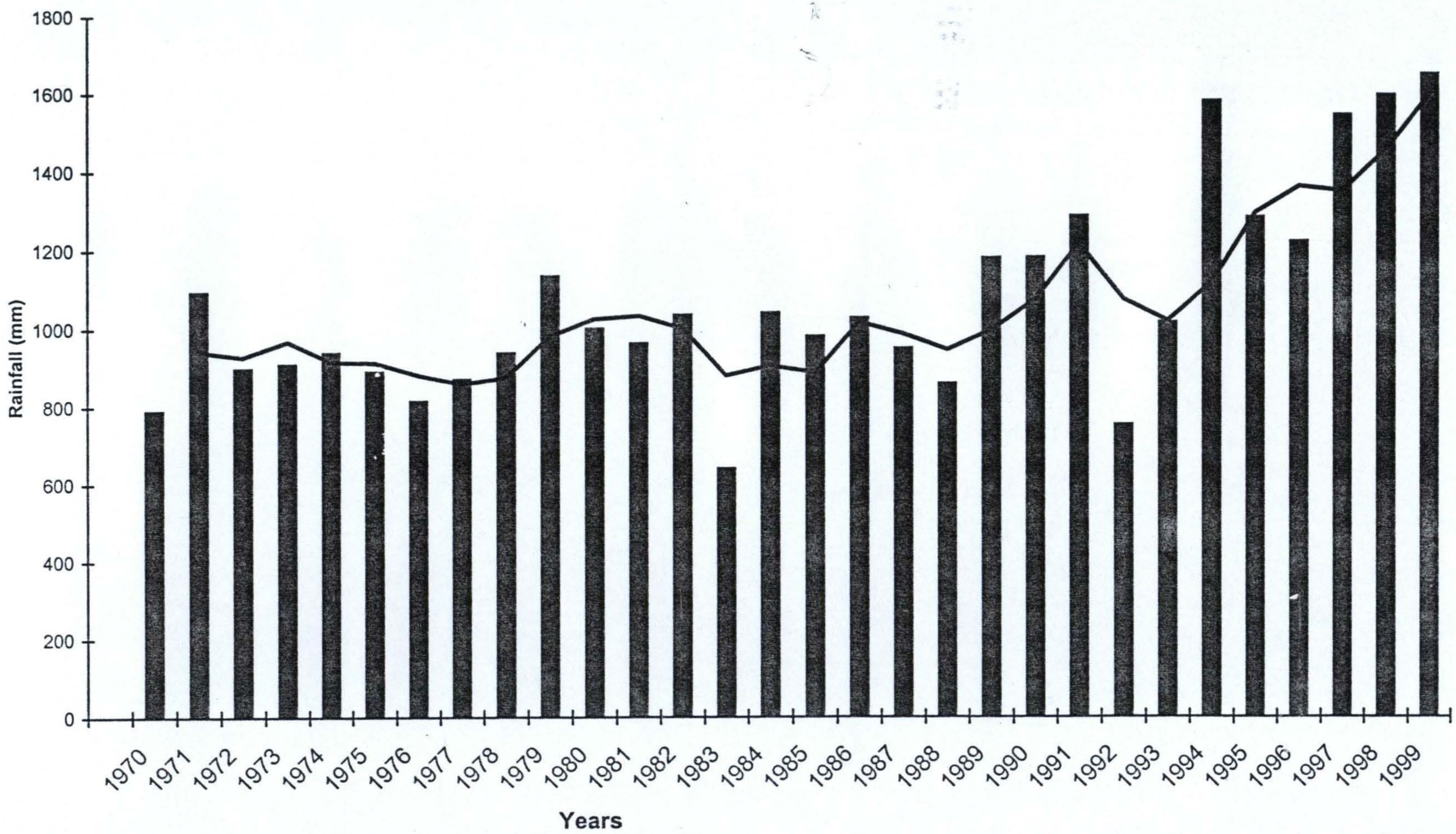


Fig. 2.4 Total Annual Rainfall and Three-year moving average for Kainji Dam from 1969 to 1999

practices, and oceanographic and climatic fluctuations or changes. Philander (1990) was of the view that 1972 and 1973 climatic fluctuations resulted in shifting ocean currents, sea surface temperatures, and wind patterns that may have been partly responsible for the general reduction in fish landings, (specifically in Peruvian coastal waters). The anchovy population there depends on an upwelling of nutrient-rich cold deep water to the surface. In 1972 and 1973 a phenomenon called the El Nino invasion of warm, nutrient poor, surface water, depleted the nutrient supply and caused anchovies to die or disperse (Philander, 1990). There are other coastal zones that depend on upwelling to provide nutrients to the fish population; all are subject to similar year-to-year fluctuations of currents and water temperatures.

Another example of the influence of climate on fish catches is the west Greenland cod supply, as indicated by Cushing (1979). According to him, up to about 1950 North Atlantic temperatures increased, and during this period the catch also increased, reaching a peak of some 450,000 tons in the early 1960s. However, since then, he noted that there has been a cooling trend, and in recent years catches of cod have been so low that they have been banned off Greenland.

2.4.3.6 Health, Comfort, and Disease

Human beings can survive environments from extremely hot (50°C) to extremely cold (-60°C). However, as Mckerslake (1972) noted, most people thrive best in a temperature range known as the "comfort zone", ranging a few degrees above or below the optimum of about 20°C. Very low or very high temperatures can negatively influence personal functions, motivation, and social behaviour. Mckerslake (1972) study has shown that in temperate latitude, workers become 2 to 4 percent less productive for every degree centigrade rise of temperature above the optimum. This explains why such workers are sluggish on hot days, especially when humidity is high. This is also a point that relates to impact of climate on man, since a change in the general patterns of temperature is likely to affect work output.

The prevalence of most diseases is also affected by climate, demonstrated by the seasonal outbreaks of certain illnesses in temperate regions and the limitations of other diseases to certain climatic zones in the tropics. Some human diseases depend on insects, snails, or other "vectors" for their spread, which are subject to temperature, moisture, and other climatic constraints.

In a globe that is warming, a number of diseases that are now mostly confined to the tropics might spread to more temperate regions. These diseases include schistosomiasis, bacillary dysentery, hookworms, yaws, and malaria. Adefolalu (1997) drew comparisons between the outbreak of respiratory diseases and Sahelian dusts brought in by hamattarn winds in Nigeria. His report gave insight into how seasonal impacts of this phenomenon coincide with outbreak of disease.

2.4.3.7 Population Settlement

If a climatic warming causes sea level to rise, the densely populated coastal regions would face serious consequences. Warrick and Oerlemans (1990) in their report show that with a 5 metre rise of sea level in the United States alone, about 11 million people would be affected. In Florida alone, they estimated that some 40 percent of the population would have to move. Other countries apart from the United States will also be affected. As Barnett (1988) observed, it is obvious that a slight sea level rise would affect most coastal areas of the world. Drought as the opposite of floods is equally disastrous such as the case of the Sahelian disaster of 1968-1973, where over 250,000 North African nomads died (Flohn and Nicholson, 1980)

2.4.3.7.8 Tourism and Recreation

Tourism is a growing industry worldwide. An increasing number of communities, and even entire countries, are becoming dependent on the income from tourism. It is an important economic sector that is also remarkably sensitive to climatic variations and change. For example, a ski resort without adequate snowfall will lose its usefulness just as drought is capable of destroying game and game viewing in the savanna regions.

One major fear expressed by many during the 2002 winter Olympics was the rather thin layers of snow for the games. Many observers pointed to the possibility of climate change.

2.5.0 Solar Radiation and Radiation Dependant Factors

According to the Science and Technology Encyclopedia (1982), on a global basis about 50% of the total incident radiation from the Sun is reflected back to space by clouds, 15% by the earth's surface, and about 5.3% is absorbed by bare soil. Of the remaining 29.7% about 1.7% is absorbed by marine vegetation and 0.2% by land vegetation. The remaining amount of solar energy reaching the earth is basically the energy used for sun drying and solar power.

The inclination of the earth's axis of rotation at an angle of 66.5° is the main factor that determines the amount and distribution of radiation received by various parts from the sun.

As one moves towards the equator the intensity and amount of radiation income per unit of surface area increases and vary throughout the year. In Nigeria as in other tropical countries, climatic changes throughout the year are more dependent on rainfall rather than radiation, since variability of radiation throughout the year is minimal. Thus around Kainji Lake and other Parts of the Country, trials with the solar dryer is based on the consideration of rainy or dry season, since radiation is distributed fairly evenly throughout the year.

2.5.1 Incoming radiation at the top of the atmosphere (Qa)

The amount of energy supplied by the sun, reaching outside the earth's atmosphere is called solar constant given as 1.94cal cm^{-2} min^{-1}. When differences of day length and solar declination are considered, every kilometer square outside the earth's atmosphere receives 307,570 cal cm^{-2} $year^{-1}$ at latitude 7^0 N and 302,590 cal cm^{-2} $year^{-1}$ at Latitude 13^0N extreme north of Nigeria. This difference has implications for the actual amount of radiation that eventually reaches the earth's surface. Kowal and Knabbe (1972), showed that seasonal variation in daily solar radiation increases with Latitude. This range between 855 in Latitude 0^0 to 720 cal cm^{-2} day^{-1} in Latitude 13^0 N in January and 791 cal cm^{-2} day^{-1} to 891 in lat 13^0 N. There is a general decline in the amount of radiation from October to February more pronounced in higher Latitudes. This is due to reduction in global radiation at this period.

2.5.2 Global Radiation (Q)

As incoming solar radiation QA passes through the atmosphere, much of it is reflected, absorbed and scattered by gases and dust in the atmosphere. The amount reaching the earth's surface varies according to Latitude and cloudiness. The amount of solar radiation that eventually reaches the earth's surface is referred to as global radiation (Q). Global radiation is made of diffused radiation from blue sky, haze, clouds etc and this forms the actual energy potential available for solar drying in an area.

Amount of global radiation (Q) also varies with Latitude across Nigeria. The Linear correlation coefficient between the amount of annual radiation and Latitude given by Kowal and Knabbe (1972), is :

$$r = + 0.80$$

Thus they were of the view that the average annual radiation of a place increases about 4.47Kcal cm^{-2} for every increase in degree of Latitude. The distribution of global radiation in Nigeria was shown to range from 330cal cm^{-2} day^{-1} in August at latitude 7^0N to 500 cal cm^{-2} day^{-1} in Latitude 13^0N and from 450 cal cm^{-2} day^{-1} in March (Lat. 7^0N), to 520 cal cm^{-2} day^{-1} in lat.13^0N.

Because of the latitudinal variation of global radiation across Nigeria, the need has arisen to study the performance of the designed solar dryer across different latitudes from the south to north of Nigeria. This is to test if it is capable of drying fish across the country irrespective of latitudinal factors. The dryer is also to be tested in the dry and rainy seasons.

2.5.3. Sunshine Duration

Clouds strongly modify the pattern of radiation across Nigeria. Cloud cover is primarily responsible for the reduction of average annual sunshine hours to about 6.5 hours per day at latitude 7^0N and approximately 8.7 hours per day at Latitude 13^0N (Udo, 1999). This implies more available sunshine for drying fish as one moves northwards. Udo (1999) noted that during the long dry season in northern Nigeria, bright sunshine is reduced by 20% than the actual potential.

This is because of hamattarn dust and clouds at high altitudes prevalent at this time.

2.5.4. Sunshine, Radiation and Temperature around Kainji Lake

At New Bussa where most of the drying trials were conducted, duration of sunshine starts increasing in October from 8 hours to 10 hours in December when the sun may rise as early as 8am and set by 7pm (See figure 2.5). While the hours of sunshine is at its maximum in December / January, solar radiation is significantly reduced due to absorption and scattering of the incoming solar energy by the dense prevailing Harmattan dusts and other aerosols. Monthly radiation for the study site is lowest in January and highest in April and September/October (Figure 2.6). A minimum of 150cal/sq cm is observed in January, which rises to 250cal cm^2 in May and declines to 134cal cm^2 in December.

Though the microclimatic effect of the lake on the NIFFR station close to it has not been fully investigated, a comparison of data collected at the station compared to others further hinterland show microclimatic modifications. NIFFR has a much-lowered maximum temperature than Mokwa and Yelwa, but its minimum temperature is high. This is due possibly to the close proximity of the lake.

The effect of bush burning further escalates the high diurnal ambient temperature in the entire basin except around forest reserves.

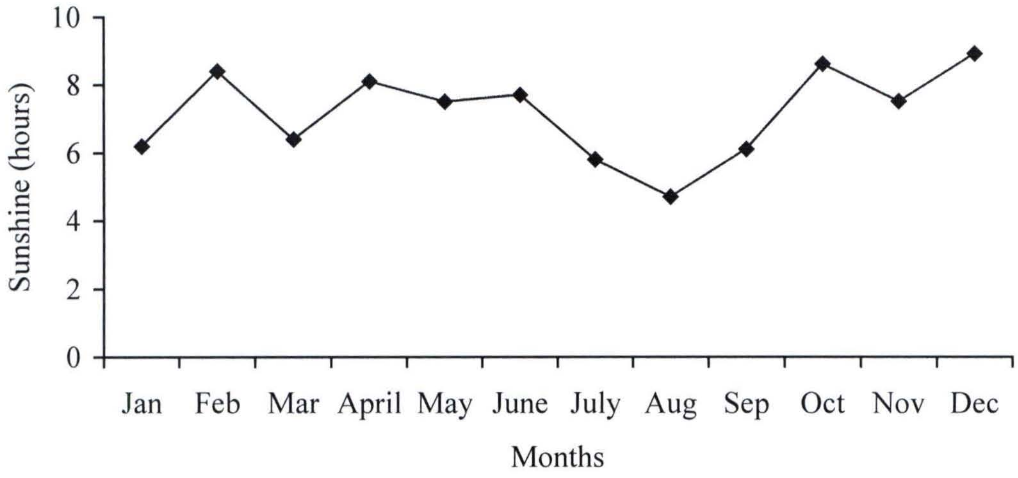


Figure 2.5: Mean monthly sunshine (hours) for New Bussa in 2001

Source: NIFFR Meteorological Station

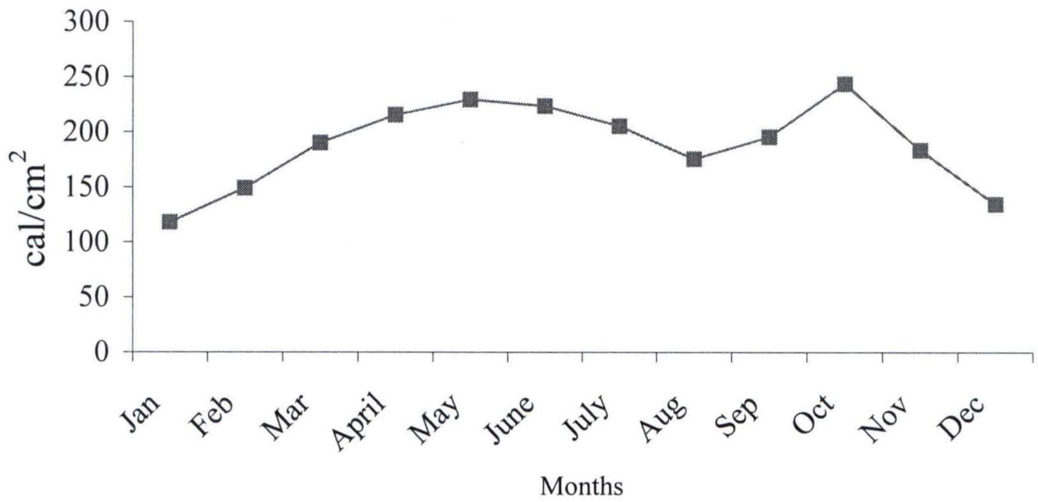


Figure 2.6: Mean Monthly net radiations in cal/cm^2 for New Bussa in 2001

Source: NIFFR Meteorological Station

As from February, formations of clouds begin in the basin. This is a departure from the prevalent dusty and hazy atmosphere, which begins from November. The eventual recession of the cool hamattarn by the end of February and the appearance of clear skies with occasional clouds mark the beginning of the hottest periods in the basin.

Figure 2.7 shows that temperature steadily begins to rise from 24^0C (minimum) and 30^0 C (maximum) in March. Maximum temperatures rise from 33^0C in January to a peak of 39^0C in March / April (See figure 2.7). With the first few rains, the heat eventually reduces. Temperature begins to decline and reach as low as 22^0C (minimum) and 29 ^{0}C (maximum) in August. It begins to rise again with declining rainfall to a small October peak but declines thereafter to as low as 16^0C in January.

Relative humidity begins to rise from 43% in January to a peak of 96% in August. It then declines through October to 59% in December. Relative humidity pattern of the area is determined by the prevailing winds. When the moisture laden South West Monsoon winds prevail as from April, humidity rises and coincides with period of highest rainfall in August. By November when the dry hamattarn winds begin to blow relative humidity begins to drop and remains low throughout the period till April. It is this pattern of humidity, rainfall and temperature that makes the dry season most preferable for fish drying by the local fisher folks.

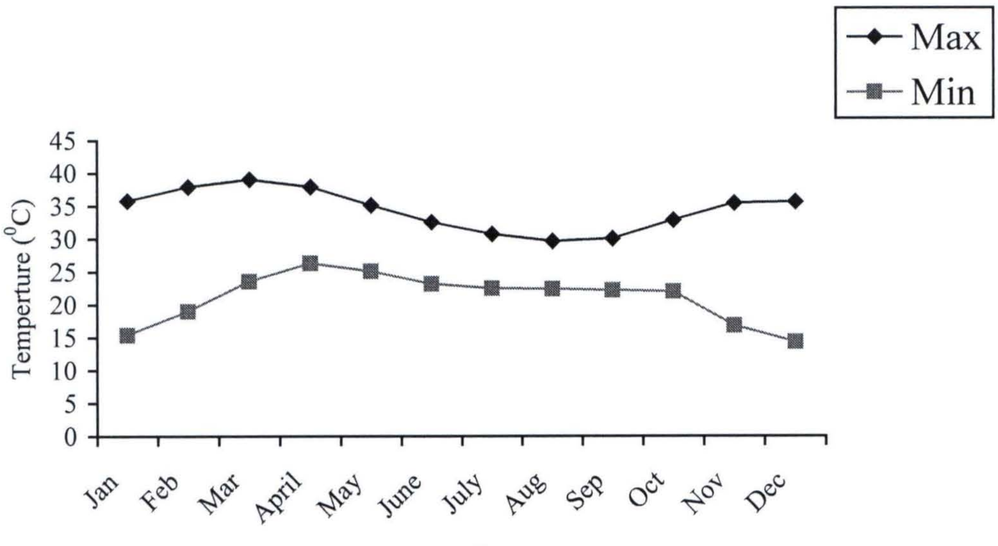


Figure 2.7: Monthly means of daily maximum and minimum temperature for New Bussa in 2001

Source: NIFFR Meteorological Station

2.5.5. Rainfall of Kainji Lake Basin

Sporadic storms, commonly observed at night, mark the onset of the rains in April. In some years though, a few stations have experienced light showers before April, such as in Yelwa (February, 1957), Kontagora (1953 and 1960 in February) as pointed out by Olokor (1995) (See also Appendix A). Normal duration of the rainy season is seven months with the peak in August. However rainfall peaks vary. It may shift backwards to July or forwards to September as it was for NIFFR 1993 and 1994. Figure 2.8 shows typical monthly rainfall distribution for New Bussa

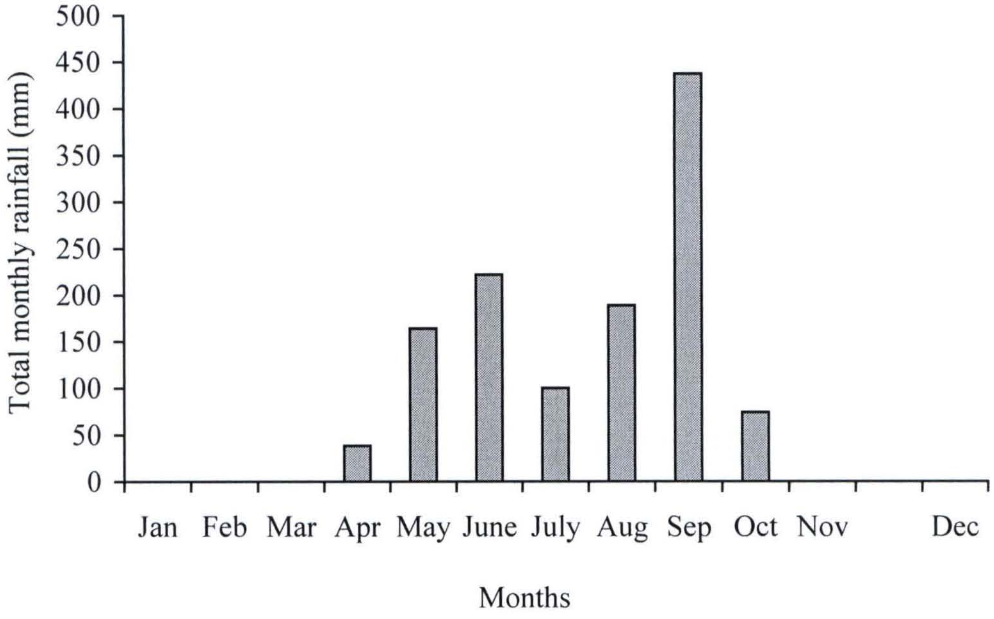


Figure 2.8: Total monthly rainfall (mm) of study site for New Bussa 2001

Source: NIFFR Meteorological Station

Local factors of relief or microclimate may alter the normal decreases of rainfall from south of the basin to the north. Table 2.1 shows that rainfall for Mokwa, Latitude 9° 18'N is 1123mm and decreases northwards to 1103mm at Salka Latitude 10° 22'N; 1015mm at Old Agwara Latitude 10° 29'N and 1006mm at Yelwa Latitude 10°53'N. Local variations could be observed at Wawa, Latitude 9°

55'N and Kontagora Farm Center Latitude 10° 25'N that had much higher rainfalls than even Mokwa further south and Kainji Lake close-by.

Table 2.1: Rainfall stations in Kainji Lake Basin

Station	Latitude ^{0}N	Longitude ^{0E}	Approx. Height (m)	Average Annual Rainfall (mm)	Effective length of wet season
Yelwa	10.53	4.45	150	106	161
Salka	10.22	5.59	305	1103	179
Kontagora	10.25	5.28	400	1222	190
Auna	10.12	4.44	200	1000	187
Wawa	9.55	4.26	260	1220	490
Kainji	9.51	4.35	110	950	197
Mokwa	9.18	5.04	150	1123	197

Source: Olokor, J.O. (1995)

The duration of rains distinctly decreases northwards as seen in Table 2.1. Only Kontagora was an exception with 190 days comparing with stations down south. This is due to its high altitude of 400m compared to 140m Old Bussa and 200m Auna.

Over a period of 40 years, the maximum total annual rainfall recorded at Yelwa was 1341mm in 1962, while the minimum was 637mm in 1951. For 50 years average maximum annual rainfall for Kontagora district office is 1653mm in 1975 and the minimum 903mm in 1961. At Mokwa the average maximum annual rainfall recorded over 30 years is 1283mm in 1955 and 664mm minimum in 1950. Put together, the average annual rainfall for the basin is just about 1000mm (Olokor, 1995).

The Nigerian Meteorological Service approximates annual onset of rainy season for the basin at 20th - 30th April and cessation of the rainy season at October 6th-16th. Often the rains may come earlier or go late as in 1994. In 1994, the first rain was recorded on 2nd of April and the last on the 26th of October. About 70% of rains recorded in the basin fall at night and are often accompanied by storms. The frequent occurrence of storm is due to local disturbances of strong winds moving eastwards against the major southwest moisture laden winds.

CHAPTER THREE

MATERIALS AND METHODS

This chapter discusses the experimental design and materials put in place to achieve the objectives of the study. One of the objectives of the study as shown in chapter one is to design and test the performance of a cheap, simple and adoptable solar dryer using meteorological and weight loss parameters within and outside the dryer.

3.1 Design, Construction and Operation of the Solar Dryer

The solar tent dryer of Doe *et al.* (1977) has been discussed earlier on in chapter two. The NIFFR design called the Olokor Solar Tent Fish Dryer (figure 3.1) is made of five wooden sticks constructed into a tent framework with the following dimensions:

Upper length: 194cm	Slant height: 180cm
Bottom length: 227cm	Vertical height: 180cm
Bottom width: 120cm	

The tent framework is dug 12cm into the ground. The sticks were nailed or fastened together by rope. The drying rack is not dug into the ground like the Doe *et al.* (1977) design, instead with the aid of a kuralon rope it was suspended from the horizontal top wooden pole of the tent about 90cm from the ground. The rack was constructed with ant proof wood and wire gauze. It had a dimension of 150cm by 70cm. Below the rack are 30 large pieces of stones

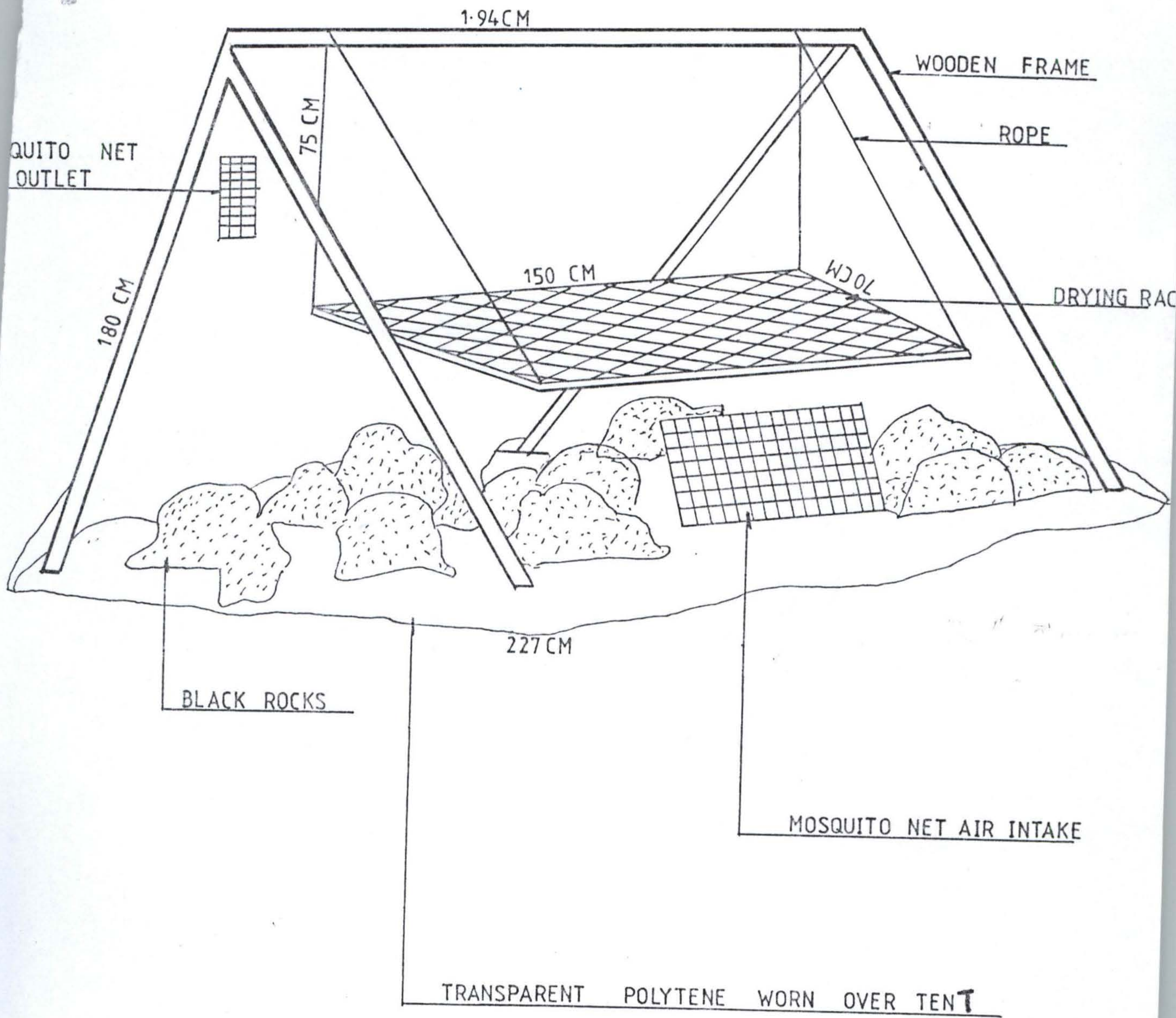


Figure 3.1: Schematic Diagram of Adapted Solar Dryer

each weighing about 40kg on the average. The stones were painted black with local dye to increase their ability to absorb and store radiant energy. A polyethylene cover of gauge 500μm sewn into shape to fit the wooden framework served as the greenhouse medium for the solar dryer. The transparent cover has slightly larger dimensions than those of the wooden framework described above. At the apex of the two vertical sides, are air exit holes screened by mosquito mesh size cloth. Each of these vents is 12cm by 6cm and located 102 cm from the bottom of the tent. Near the base of one side of the horizontal length of the tent is another large vent, 35cm from the base and 24cm by 24cm in dimension. At the middle opposite side of the horizontal length of the tent is a 1m zip sewn to the tent. This serves as access to the fish during the drying process. Around the entire base of the polyethylene tent is a rope fitted to it, which serves as a fastener of the tent to the wooden framework to reduce interference by wind.

To set up a solar tent fish dryer the following steps are to be taken into consideration:

a. A suitable location, which is exposed to sunshine throughout the day.
b. A site cleared of grass and dirt. Grasses can contribute moisture to the tent chamber during the drying process through transpiration.
c. A wooden framework set up as described above. But the longest side of the tent should be aligned to the path of the sun to have more direct exposure of fish to the sun throughout the day.

d. Thirty pieces of rocks should be stacked at the base of the wooden framework and painted black (See Plate XVII in Appendix C). These hold more energy than black polythene used in the Doe tent and for a longer period too. Tar or lead paints are not to be used because injurious properties could be transferred into the fish during drying.

e. Ten yards of transparent polyethylene sheets (gauge 500μm) should be sewn to the dimension of the wooden framework described earlier on.

f. One hundred and fifty centimeters length of 2cm chicken wire mesh and 2 lengths of 2 x 2 hard wood should be framed around the wire mesh as a drying rack with the dimensions already given.

g. The drying rack should be suspended from the horizontal length of the wooden framework.

h. The sewn polyethylene cover should be used to cover the wooden framework.

The solar dryer was set out in place before the fishes are put inside. Care was taken not to allow any fly enter during this process. The fishes were turned twice a day during the drying process. The drying rack was adjusted to slant position to drain away excess moisture from the fish and to have contact with direct sunshine at an advantaged angle. This is a modification of the Doe *et al.* (1977) fixed rack type. In the mornings the apex vents of the solar dryer were closed to build up the temperature. But at midday they are opened to prevent temperatures reaching over 55°C, similar to methods used by Trim and Curran

(1983). This is to prevent case hardening; a situation where the very high initial temperature causes the outside of the fish to dry faster than the inside thus preventing moisture loss from the fish.

Drying commenced by 8.00hours to 18.00hours. During the first day drying, care was taken to handle the fish when been removed for storage so as to prevent the samples turning sour by morning. Unlike the overnight storage, methods used by Trim and Curran (1983) whereby, the fish were press piled in plastic bins, the fishes in this trial were laid out on trays in well ventilated room free from rodents. This is in accord with traditional practice and it was observed in the course of the study that some weight loss took place over night, which is an added advantage.

3.2 Experimental layout, Instrumentation and Meteorological data collected

The site of the main experiments for this study was in the premises of the National Institute for Freshwater Fisheries Research, New Bussa, Niger State. A suitable site free from human and animal interference, which has sufficient exposure to the sunlight throughout the day, was selected. The solar tent fish dryer was constructed from materials obtained locally. Close to the solar tent dryer the traditional practice, which in the case of Kainji consist of blue polyethylene sheets spread on the ground for drying fish, was set up. Near the experimental site is NIFFR meteorological station where vital meteorological data were collected (See Plates I and ii)

Plate I: NIFFR Meteorological Station

Plate II: Solar dryer rocks, rack and measurement of some parameters.

At the drying site certain instruments were installed to collect specific data as illustrated in Table 3.1

Table 3.1: Types of Data collected and Instruments used

Type of Data	Instrument for data collection
Daily radiation (Cal/cm2) outside solar dryer	Gumbellani (Lintronic Ltd, 54-58 Bartholomew Close, London, EC1A 7HB)
Two-hourly ambient air temperature (^{0}C) within and outside the solar tent dryer	Temperature recorder (Grant Instruments (Cambridge) Ltd, Barrington, Cambridge, Cambridgeshire
Two-hourly Relative Humidity (%) within and outside the solar tent dryer	Hygrometer [Prazisionshygro (multitherm)] Germany]
Daily wind speed (Km/hour) Out side solar dryer	Cup Anemometer (C.F. Casella and Co. Ltd.)
Weight loss of fish within and outside solar tent dryer	Salta sensitive electronic weighing balance

At the nearby meteorological station, daily data on sunshine duration in hours using a Campbell stokes sunshine recorder and radiation using a Gum Bellani radiation recorder in cal/cm^2 were collected.

Two hourly records of all meteorological and weight loss parameters were taken for days of fish drying in March and August 1999 and March and August 2000. These are the peak of dry and peak of rainy seasons in the study area. In the dry season, records were taken for 3 days' period of drying and 5 days for rainy season. Data were collected within and outside the Olokor and Doe solar dryers.

3.3 Fish Preparation and Experimental Treatments.

Fishes to be used for the trials were obtained fresh. The gills, eyes etc were checked for freshness. Only fresh fish is recommended and was used in the trials. Frozen fish was not used. The fishes were washed and split along the backbone from head to tail in accordance with traditional practice. All the guts and gills were removed (Plate iii - vi). The fishes were then thoroughly washed with sponge so that no bloodstains could be seen. This is meant to give the final product a clean and attractive look that will command better market prices. Before and after splitting the fishes they were weighed and then placed in the solar dryer (Plate vii). The most commonly dried fish by traditional fishermen around Jebba and Kainji Lake Basin is *Bargus bayad*. In the traditional set up freshness of fish is not taken into account before drying. The fishes to be sun-dried are split from the dorsal part like those used in the dryer, however the gills and fins are not removed and the fishes are not washed before drying. For the study, the fishes to be dried in the traditional way were treated as described. However the quality of the fish is similar to that put in the dryer so as not to introduce bias to the final results.

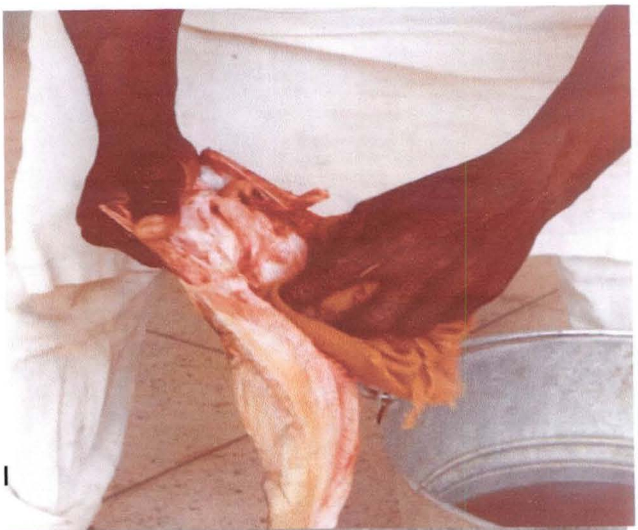


Plate V : Weighing washed fish

Plate VI :Labelling gutted fishes

Plate III - VI: Steps of preparing fish for drying.

Plate VII: Putting gutted fishes into Solar dryer.

All the fishes prepared (both those for the solar dryer and traditional open sun drying) were divided into three parts for the treatments as explained below:

a. Brined fish samples: these were gutted and soaked in 10% salt solution for 30 minutes before being put into the solar dryer or spread in the open sun in accordance with fish processors practice.
b. Dry salted fish samples: These had dry salt rubbed uniformly all over them as done by local fish processors. This is about one gm of salt to 50gm of fish.
c. Unsalted fish samples: These were left untreated and put into the dryer or spread in the sun without any treatment.

3.4 Testing the Quality of Dried Fish Product.

3.4.1 Sampling Dried fish for Quality Assessment

To determine the quality of both fishes dried in the solar dryer and those dried in the open sun, quadruplicate samples of all of the batches of the final dried products were analyzed for moisture, ash, crude fiber, crude protein, ether extract and Nitrogen free extract at NIFFR laboratory. Analyses were done in accordance with regulations of the Association of Official Analytical Chemist (1980).

3.4.2. Organoleptic Test

For the organoleptic assessment, a panel of 10 assessors was set up. Pieces of solar dried fish and traditionally sun-dried fish were served to them. The panel members were not aware of the differences in the samples. A score sheet with scale 1 – 10 was given to each member to score each of the samples according to taste, colour, smell and texture. The mean score for each parameter are discussed in the section of results.

3.5 Methods of Fuel wood and Deforestation Estimation

To meet the objective of estimating the amount of fuel wood used for smoking fish around Kainji Lake and the implications of the practice on the forest resources, the quantity of fuel used was estimated by weight while forest loss was estimated by satellite imageries.

3.5.1 Estimation of Fuel Wood by Weight

The large fish catch from Kainji Lake, which requires daily processing, and preservation has led to sharp rise in the demand for fuel wood. Fish processors around the Lake now source for wood at all cost around the Lake Basin not minding the impact on the forest. The persistent felling of resourceful forest trees has serious implications for the forest resources. One of these is deforestation.

The study was carried out in four fishing communities namely Malale, Monia, Warra and Yauri. Questionnaires were administered to a total of 76 respondents in all the communities. Information sought from fish processors include: weight of fuel wood used daily for smoking fish, cost and source of the wood, quantity and cost of fish smoked daily and the species of wood used for smoking fish.

A 50kg Salta scale was used to weigh the daily wood requirement of the 76 fish processors in the four communities. Projections of weekly and annual consumption of fuel wood, cost, weight of fish smoked and their cost were made using 6 days in a week and 317 days a year since over 75% of the respondents were Christians from the Niger Delta area who claimed not to work on Sundays.

Calculations of the volume of fuel wood consumed by each processor were based on the formula: $\pi r^2 h$ similar to Huber, Smalian and Newtons method (Sci. and Tech. Ency., 1982)

Where $\pi = 22/7$

r^2 =square of radius of log of wood of known weight

and h= height of log of wood.

For cuboid shaped woods the product of the length, width and height divided by the weight in Kilogramme gives the volume in cubic meters per kilogramme.

3.5.2 Estimation of deforestation by Satellite data

LANDSAT MSS and SPOT XS satellite imageries for Kainji Lake Basin for 1976 /1978 and 1993 / 1995 (Appendix C) were obtained from FORMECU, Abuja, to estimate differences in forest cover between the periods to show the level of forest removal. This was done in conjunction with Ikusemoran (2000). 'Ground truth' to confirm some information on the imageries was done, using a Magellan Blazer 12 GPS (Geo Positioning System), around the major fishing villages selected for the study.

The 'Ground Truth' survey to check spectral signatures of natural surfaces presented on the satellite maps obtained from FORMECU was carried out in August (period of high rainfall) and in January (dry period). Three categories of vegetation were targeted. These were: forest plantation, undisturbed forest and grasslands. The various colour bands confirmed as belonging to the three groups from the ground survey were digitized and analysed by GIS (Geographical Information Systems) program (ESRI 3.0). Using the tools available in the GIS package the area cover in km^2, the digitized colour bands were computed. The results of the analyses of the 1976 /1978 and 1993 / 1995 imageries are shown in chapter four.

3.6 Pilot Trial of solar Dryer in Eco-Zones of Nigeria

An appraisal of the capability of the developed solar dryer across Nigeria was carried out. The aim is to obtain a general picture of how well the developed dryer will perform across Nigeria. Weight loss of fish in the solar dryer was taken to assess the rate of moisture loss. The five eco-zones chosen for this study were:

a. Forest Belt (College of Education, Warri, Delta State), Latitude 5° 30′,
b. Wooded Savanna (Forestry Research Institute, Ibadan. Oyo State), Latitude 7° 22′,
c. Guinea – Sudan (NIFFR, New Bussa, Niger State), Latitude 9° 51′,
d. Sudan – Sahel (School of Forestry, Jos, Plateau State), Latitude 9° 53′, and
e. Sahel (Federal College of Freshwater Fisheries Technology, Baga. Borno State), Latitude 13° 1′.

Suitable sites were obtained at each of the zones where the trial took place. Care was taken to ensure that the selected sites were exposed to sunlight throughout the day so as to avoid the shade of trees or houses, which are capable of affecting the drying process. In each of the zones, a suitable source of fresh fish was located so as to get the fishes as early as possible to the drying site, since frozen fish is not to be used for the trials.

The procedure for drying the fish follows those already stated. The tent is set up as early as possible before sunrise. The fishes were split from the dorsal part, gutted and thoroughly washed, salted and put into the dryer.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1. Introduction

In this chapter, the experimental results as they relate to the objectives of this study are discussed. The results leading to the achievement of each objective are discussed in the sections below.

4.2 Design and Testing of Solar Dryer

To achieve the first objective of the study which is to design and test the performance of a cheap, simple and easily adoptable solar dryer using meteorological and weight loss parameters within and outside the solar dryer, it is necessary to show the results of outcome of the final design of the Olokor solar dryer.

4.2.1 Construction of the Olokor Solar Dryer

The final design of the Olokor solar tent dryer has the following dimensions: Upper length: 194cm; Bottom length: 227cm; Slant height: 180cm and Vertical height: 120cm

The tent was constructed using sticks of 18cm diameter. Four of these were dug 12cm into the ground according to the specifications given earlier. The sticks were fastened by ropes to form the shape of a tent. A sewn transparent polyethylene sheet of 500μ gauge was draped over the frame. This serves as a green house medium that allows solar energy through but traps the terrestrial energy to heat up the chamber below. This heating coupled with the black rocks arranged around the base of the dryer, cause a draught condition in the chamber, leading to the drying of fresh fish placed on the drying racks within the chambers.

4.2.2 Comparison of Olokor Solar Dryer with Doe Type

4.2.2.1 Structure of tent

In designing the Doe type, Trim and Curran (1983) simply dug the sticks into the ground, tied them and fastened the polyethylene sheets around the sticks using stapling pins. A flap was left under the tent to serve access to the fish and also as air inlet. According to them, this had numerous disadvantages including influx of flies, which affected the quality of the fish during drying, heat loss and poor regulation of stored heat during the drying process. But in the Olokor design, the polyethylene cover was sewn into the shape of the wooden framework. The sewn polyethylene sheet also had special air inlet attached with screen and outlets attached with screens also. Table 4.1 shows a comparison of the Doe solar tent dryer and the Olokor type designed during this study.

Table 4.1: Comparison of Doe (1977) and the Olokor (2003) Solar Tent design

Doe (1977) Solar Tent	Olokor (2003) Solar Tent
Polyethylene tent not sewn but wrapped around the wooden frames	Polyethylene tent sewn to shape with roped hemmed around the tent to protect it against wind
Wooden frames are dug into the ground and not movable	Wooden frames are dug into the ground as with Doe's design
Outlet of Polyethylene tent not screened but wrapped up, thus allows in flies and pests	Outlet screened against flies with mosquito net
Tent has no screened exit for air but cut out openings	Tent has screened exit for air sewn
Tent has no black rocks but PVC (black) Polyethylene spread out on the base of the tent	Tent has black rocks to generate heat
A section of the tent has to be carried up to gain access into the tent to check fish	Tent has zip attached to serve as access into the tent
Drying rack is fixed rigidly to the ground	Drying rack is adjustable and removable

It was much easier to use the Olokor Solar Tent polyethylene cover because at night it can be removed, cleaned and kept, while the Doe type remains fixed to the structures until the end of the exercise. However, it was noticed that the Doe design resisted more winds than the Olokor type because it was stapled firmly to the tent framework. To make up for this shortcoming in the Olokor design, a rope was hemmed around the base of the entire polyethylene cover and this was used to tie the cover firmly to the framework.

In the process of checking the fish in the Doe design, there is some energy loss because the bottom flap had to be raised high to get access to the fish unlike in the Olokor design where an access zip one metre long, was provided for the cover. This zip is opened without difficulty and the small space opened in the process allows a hand into the dryer to check the fish, limiting the escape of heat from the dryer. Fish processors that used both types during the period of demonstration pointed this out and show preference for the Olokor design.

4.2.2.2 Black rocks

The major difference between the Doe design and the Olokor design is the use of black rocks as absorbers in the latter instead of black polyethylene as in the former. The black rocks absorb and store more radiant energy than the black polyethylene sheet spread on the ground. Thus the Kainji Dryer generated higher temperatures than the Doe design as shown in subsequent sections of this chapter. The use of black rocks, however, added to the cost and effort of setting up the Kainji design. It was observed that fish processors would prefer to use black PVC sheets for their dryer if not for the comparative advantage of using the black rocks. Fieldwork shows that while the black PVC cost ₦200, it will take ₦ 400 to employ a pickup to gather the rocks required for a solar dryer. The black PVC sheet is recommended for areas without rocks. But it will require more time to dry the fishes in such cases. The use of black rocks in the Olokor design also had the disadvantage of not being as portable as the Doe design. To relocate the Olokor design is more difficult than to relocate the Doe type, because of the black rocks. It was noticed on the field that processors leave the black rocks behind while relocating, since across the study area, rocks are easily available. Another alternative employed by some of the fish processors is to use concrete slabs, which they painted black in place of rocks. Though this is considered more expensive, it serves as good remedy for areas without rocks such as in the Niger Delta as was observed in the course of the study.

4.2.2.3 Drying rack

Another major innovation of the Olokor solar tent is the introduction of suspended drying rack in place of the fixed drying rack dug into the ground in the case of Doe design. Even though the Doe type of drying rack is similar in dimensions to the Olokor type. The Olokor type has a rack suspended by ropes from the top horizontal wooden pole of the tent framework. This rack can easily be removed at night. It can also be adjusted to incline at suitable angles facing the rays of the sun during the drying process. The angle of incidence of the sun's rays adds to the drying rate of the fish. In the beginning of drying, the drying rack is adjusted to a slant position to allow moisture over the fish to drain off. But in the Doe design, hours after drying commences, excess moisture was still seen gathered over the fish. This inhibits the drying rate, as it will require additional effort to first evaporate this water from the surface of the fish before actual drying commences.

4.2.2.4 Construction Cost

At the end of construction, the Doe tent cost ₦ 2,430 while the Olokor design cost ₦ 2,900 (See Appendix B). The difference of ₦ 470 is in the sewing of the polyethylene cover, the screens attached, the zip, and cost of collecting and painting of stones. Despite this difference, field experience shows that processors preferred the Olokor type because of its efficiency.

4.2.2.5 Adoption and Impact

Over 70 units of the Olokor dryer has been sold to fish processors around Kainji and Jebba Lakes. A one-time Minister of State for agriculture, Dr. Jonah Madugu, requested 36 units of the dryer for all the states' ADP. Requests for details of the technology have been received from Switzerland and Addis Ababa. Of 115 fish processors interviewed in the course of this study, 98% favoured the Olokor dryer. Plates x to xvi in Appendix D shows the introduction of the dryer to fishing villages and participation of fish processors. This technology has also featured in various NTA programmes, Science Trade Fairs, NIFFR and NARP Calendars, a German International Magazine (AT Activities), a page feature in The Guardian of Sunday 17th September, 2000 and the Nigerian Agriculture Magazine of January / February 2001.

4.2.2.6 Insect Count Inside Solar Dryers

During the course of experimental trials, numbers of flies were counted inside both Doe and Olokor Solar dryers in the two different years of trials. Figures 4.1 A and B, and 4.2 A and B, shows number of flies counted in the Doe tent and Olokor tents in a three-day trial in March and August 1999 and March and August 2000. All the trials show that the Olokor Dryer had less fly population than the Doe Dryer. In August 1999 Doe tent had an average of 14 flies counted while the Olokor Tent had 3. By March an average of 11 flies were seen in the Doe Tent while the Olokor Tent had an average of 1 fly. During the trials of 2000, Doe Tent recorded an average of 11flies while the Olokor Tent had an average of 1 fly in March. In August, Doe Tent recorded an average of 16 flies while the Olokor Tent had an average of 2. Figures 4.1 A,B and 4.2 A,B show the distribution of fly population in the solar dryers throughout the trial period and the distribution patterns during each day of trial. It can be seen that the period of most dominance of fly population in both dryers is in the rainy season (August) and between 10 am and 12 noon. The large fly population in the rainy season is due to the relative slower drying rates of fish as shown in later sections of this chapter. The higher temperatures of the solar dryers as from mid day is also responsible for lower abundance of fly infestation between 12 noon and 6 pm. Statistical analyses of Fly occurrence in both dryers show that there are significant differences ($P<0.05$) in numbers of flies in Doe Tent and Olokor Tent in both years of trials. See Table 4.2

Table 4.2 : ANOVA Results Showing significant differences between number of flies counted in Doe and Olokor Solar Dryers

ANALYSES	RESULT
March 1999	P=3.2E-28 or 3.2×10^{-28} , P=0.00
August 1999	P=8.7E-10 or 8.7×10^{-10},P=0.00
March 2000	P=9.4E-10 or 9.4×10^{-10},P=0.00
August 2000	P=1.9E-08 or 1.9×10^{-8},P=0.00

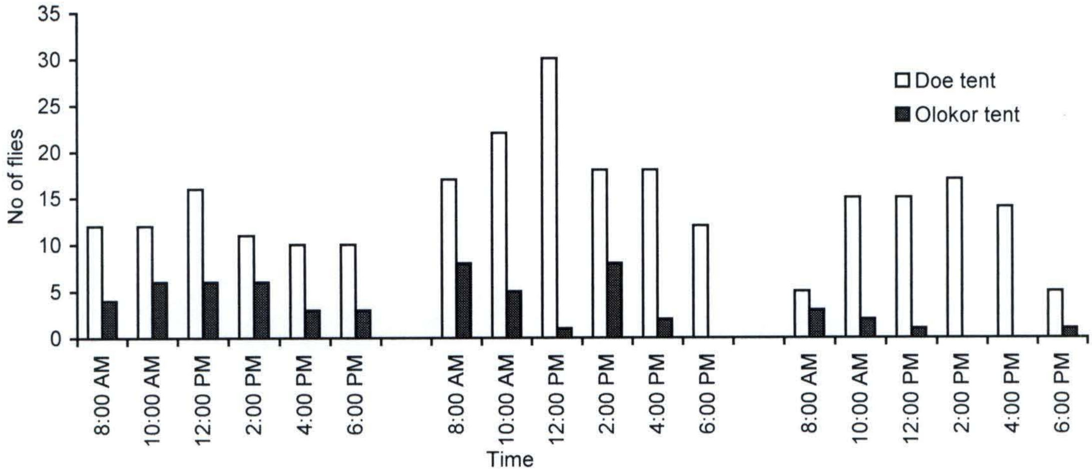


Figure 4.1 A: Total Number of flies counted inside Doe and Olokor tents every two hours over a 3-day period in August 1999

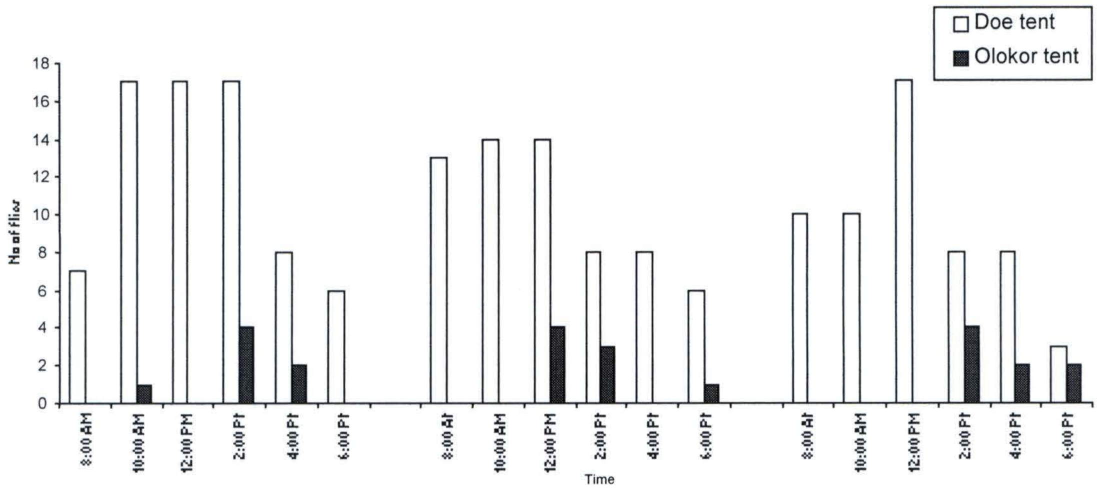


Figure 4.1B: Total number of flies counted inside Doe and Olokor tent every two hours over 3-day period in August and March1999

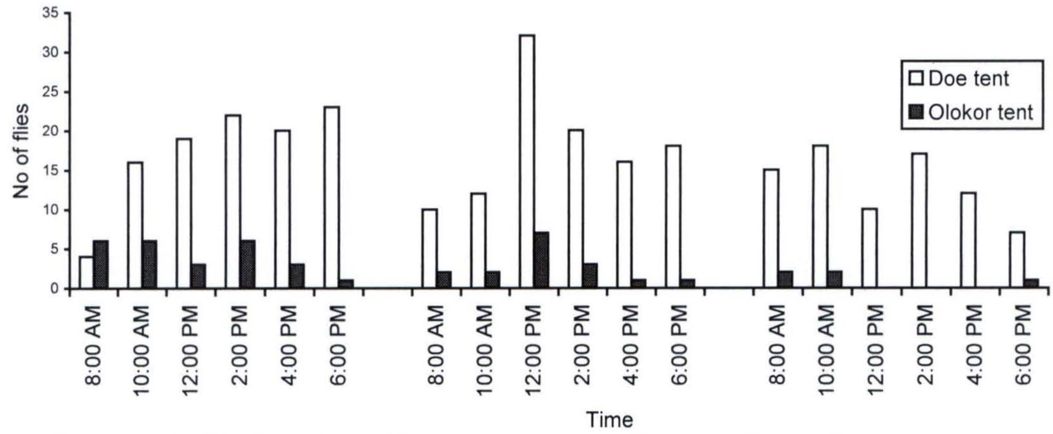


Figure 4.2A: Total number of flies counted inside Doe and Olokor Tents every 2 hours over a 3-day period in August 1999

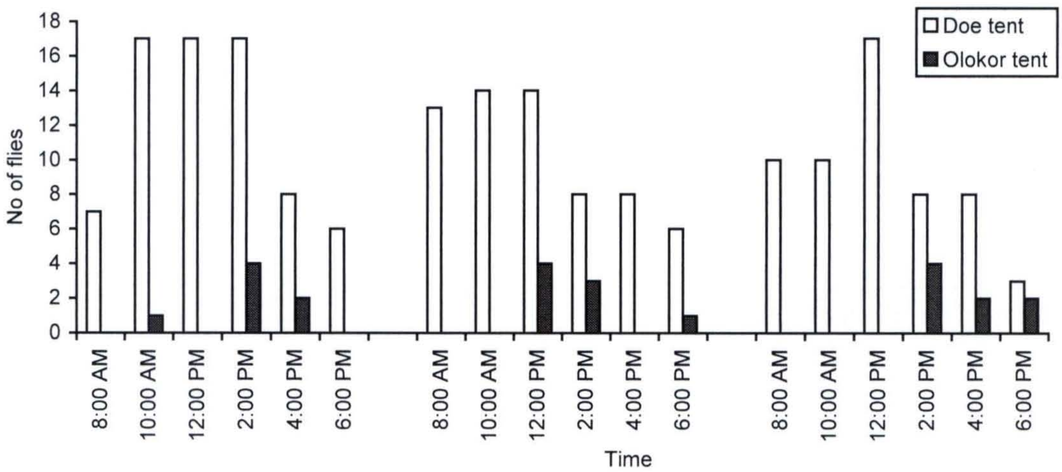


Figure 4.2 B:Total number of flies counted inside Doe and Olokor tent every 2-hours over a 3-day period in march 2000

The results show the importance of using mosquito net to screen the in-lets and out-lets of the polyethylene of the Olokor tent, which prevented flies from entering the dryer unlike the Doe design, which had no screens, and flies were observed to move in and out freely. The implication of this is that the flies lay their eggs on the fish during the drying process thereby facilitating spoilage.

4.2.3 Performance of Solar Dryers and traditional Open Sun Drying Method

One aspect of this study is to show that solar dryers particularly the one designed in the course of this study can dry fish better and faster than the traditional sun drying method (the fish processors practice). To achieve this objective, meteorological parameters such as temperature and relative humidity, which enhance fish drying, were compared in both methods. This forms the basis for making a case for the introduction of this new technology to fish processors.

4.2.3.1 Temperature Within and Outside the Solar Tent Dryers

In 1999 and 2000 two trials were conducted in March and August. Trials commenced by 8am and ended 6pm daily for 3 days. Temperature readings were taken within the Doe tent, Olokor tent and outside (where fishes in accordance with traditional practice were being dried). Figures 4.3 A,B and 4.4 A,B show that temperatures were consistently higher in the Olokor tent, followed

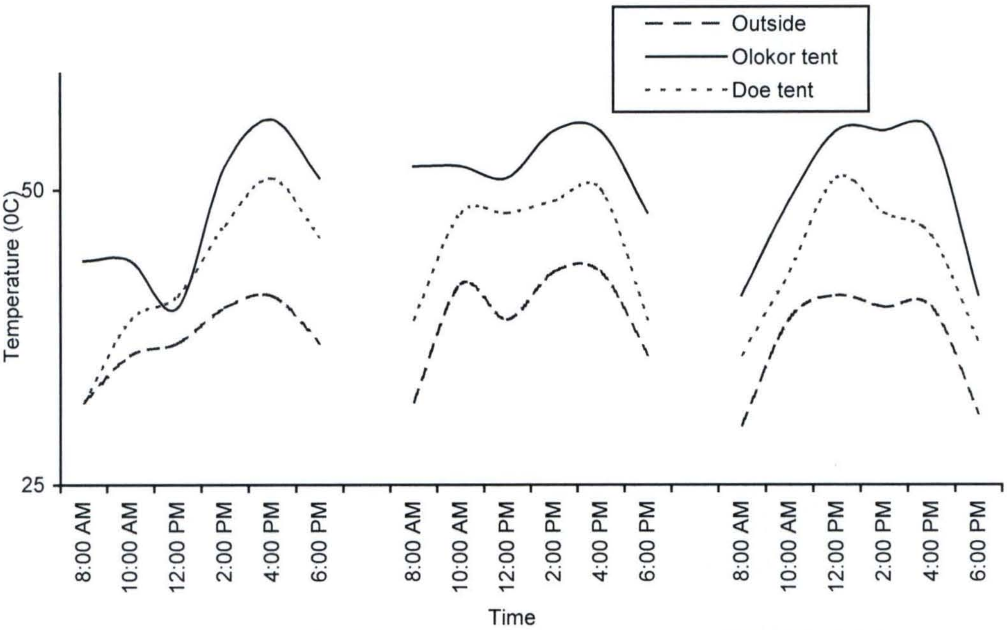


Figure 4.3 A: Temperature variation outside and inside solar dryers every 2 hours over a 3-days period in March 1999

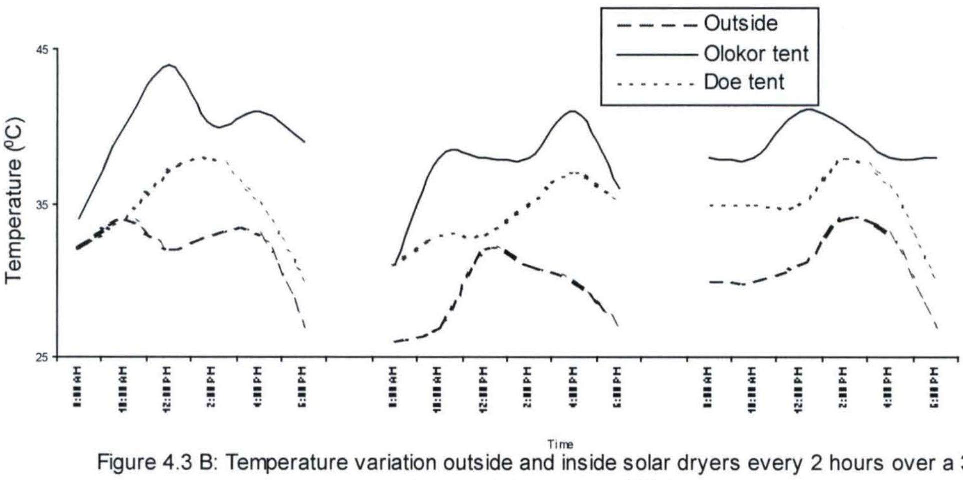


Figure 4.3 B: Temperature variation outside and inside solar dryers every 2 hours over a 3-days period in August 1999

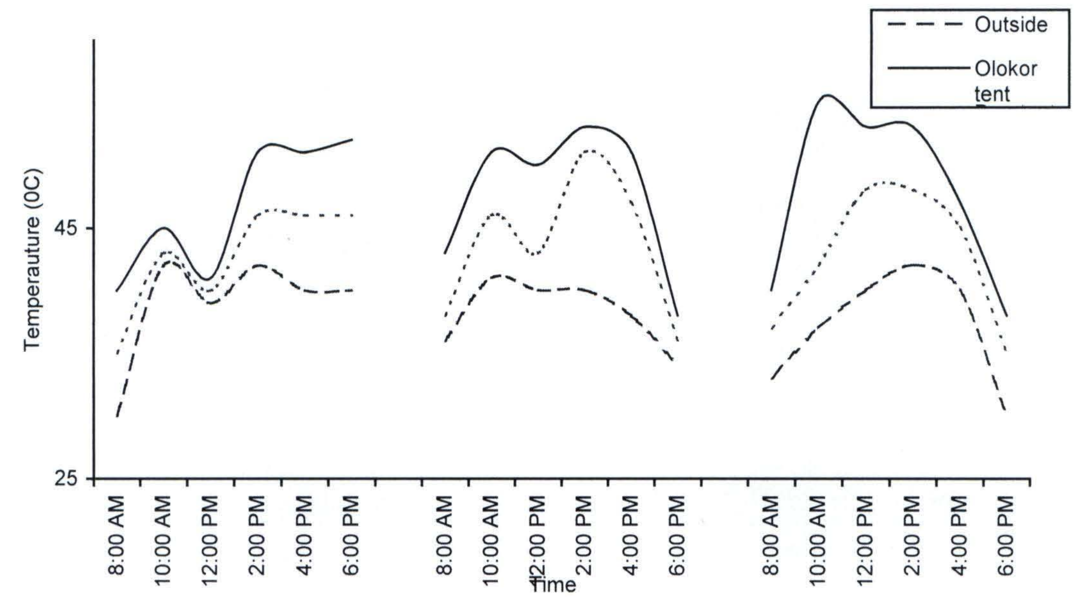


Figure 4.4 A: Temperaure variation outside and inside in solar dryers every 2 hours over a 3 days period in March 2000

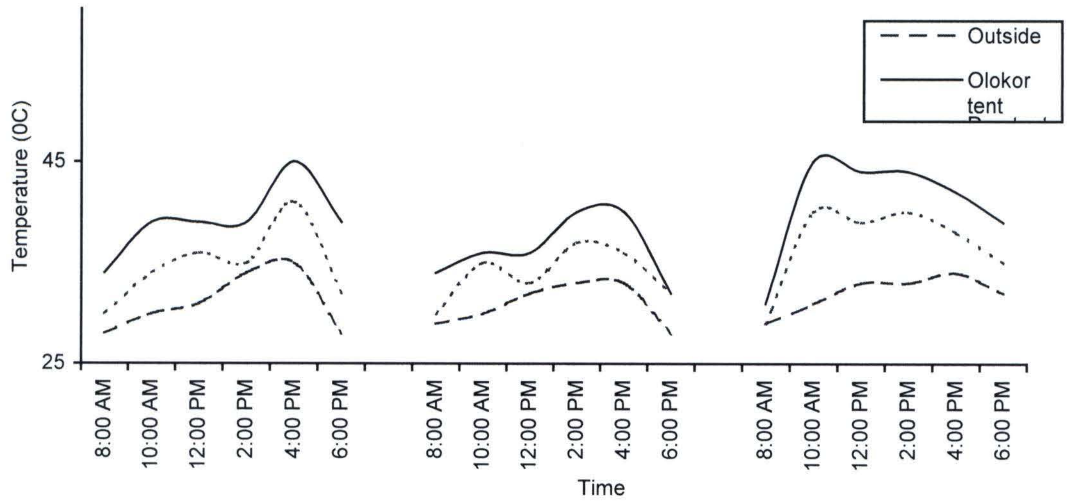


Figure 4.4 B: Temperaure variation outside and inside in solar dryers every 2 hours over a 3 days period in August 2000

by Doe and then outside. Temperature consistently increased from the start of drying in the morning and peaked in the late afternoons between 2pm and 4pm when ambient temperature conditions are highest in the study area. On a few occasions the temperature was highest by 12noon (12/8/99 and 17/3/20). Apart from these variations, the temperature generally rose from the morning; got to a peak between 2pm - 4 pm and decreased thereafter to 6pm. Table 4.3 shows mean temperatures within the Doe and Olokor tents and outside

Table 4.3 Mean temperatures inside and outside solar dryers within trial periods

	March 1999	August 1999	March 2000	August 2000
Olokor Tent	49.8°C	38.5°C	47.3°C	38.8°C
Doe Tent	43.9°C	34.4°C	42.8°C	35.1°C
Outside	37.7°C	30.5°C	38°C	31.3°C

The table shows that the Olokor tent had higher temperatures than both Doe and outside conditions. Analyses of the data show that Olokor Solar Tent had temperatures significantly different at 5% significant level from those of Doe and outside conditions as can be seen in Table 4.4

Table 4.4 : ANOVA results showing significant differences ($P < 0.05$) in temperature inside and outside solar dryers

	March 1999	August 1999	March 2000	August 2000
Olokor Tent Doe Tent	P=0.004	P=5.69E-05 or $P=5.69x10^{-5}$ P=0.00	P=0.02	P=0.01
Olokor Tent Outside	P=1.27E-08 or $P=1.27x10^{-8}$ P=0.00	P=4.03E-10 or $P=4.03x10^{-10}$ P=0.00	P=1.25E-06 or $P=1.25x10^{-6}$ P=0.00	P=1.66E-07 or $P=1.66x10^{-7}$ P=0.00

While significant differences were higher in all the trials between the Olokor tent and the outside conditions it was relatively weak compared with the Doe tent, except in August 1999. This is due to the fact that the Olokor design has more consistent internal temperatures because of its black rocks, which absorb and retain solar energy despite hourly fluctuations due to cloud cover prevalent at this time, while the Doe design is more responsive to changes in ambient conditions. This confirms that it is better to use black rocks as solar absorbers instead of black polyethylene used in the Doe design. The black rocks intensify the greenhouse effect within the dryer through its capability to store solar energy.

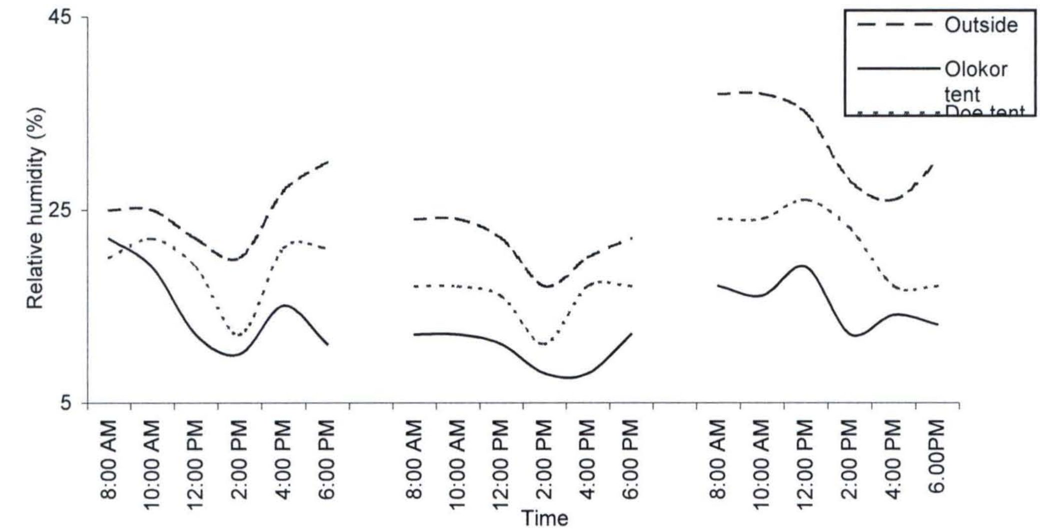
4.2.3.2 Relative Humidity Within and Outside the Solar Tent Dryers

The mean relative humidity readings taken at intervals of 2 hours during the trials of March and August 1999 and 2000 are shown in Table 4.5.

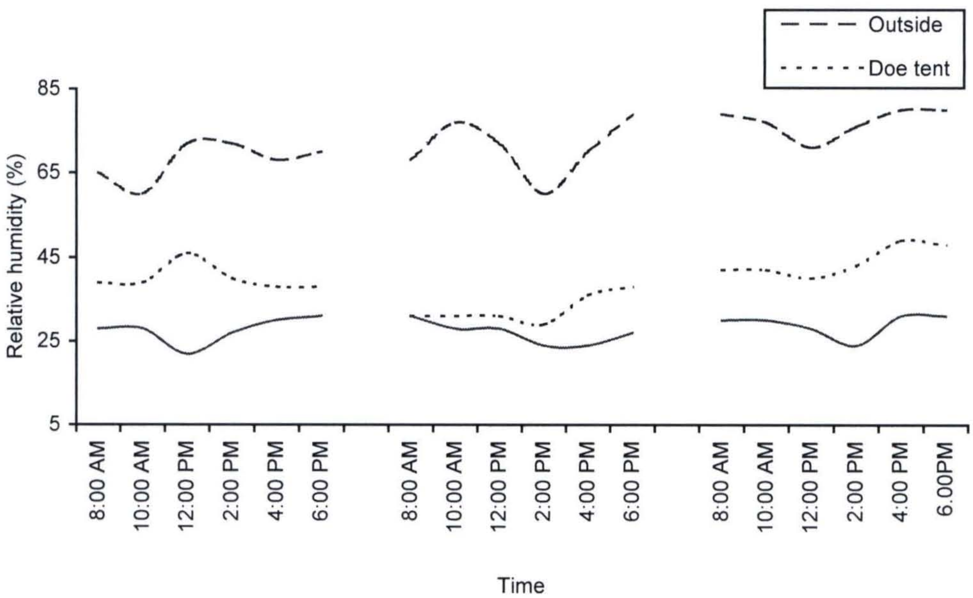
Table 4.5 : Mean Relative Humidity over a 3-day period inside and outside solar dryers

	March 1999	August 1999	March 2000	August 2000
Olokor Tent	13.5%	27.9%	10.5%	25.3%
Doe Tent	18.9%	38.9%	17.7%	35.8%
Outside	26.1%	72%	24.8%	70.8%

The lowest readings were obtained in the Olokor solar tent followed by the Doe Tent and outside conditions. March and August have contrasting humidity conditions in the study area because of the influence of rain in August and complete absence of rains in March, coupled with the prevalence of harmattarn winds. The lowest humidity of 10.5% was obtained inside the Olokor dryer in March 2000. Ambient conditions were consistently high in August but relatively lower in March. This is the reason why local fish processors engage in fish drying more at this time. Humidity is the strongest factor for fish drying either within or outside a solar dryer. This statement is supported with findings from this study in the next section of this chapter. Figures 4.5 A,B and 4.6 A,B show relative humidity trends during the study. It can be seen that humidity varied throughout the day, generally higher in the mornings and evenings and lowest late afternoons when ambient temperature is highest. As temperature rises, relative humidity decreases. Table 4.6 shows significant levels for relative humidity inside Olokor tent and those of Doe and outside conditions.



Fiugre 4.5 A: Relative humidity variation outside and inside solar dryers every 2 hours over a 3-day period in March 1999



Fiugre 4.5 B: Relative humidity variation outside and inside solar dryers every 2 hours over a 3-day period in August 1999

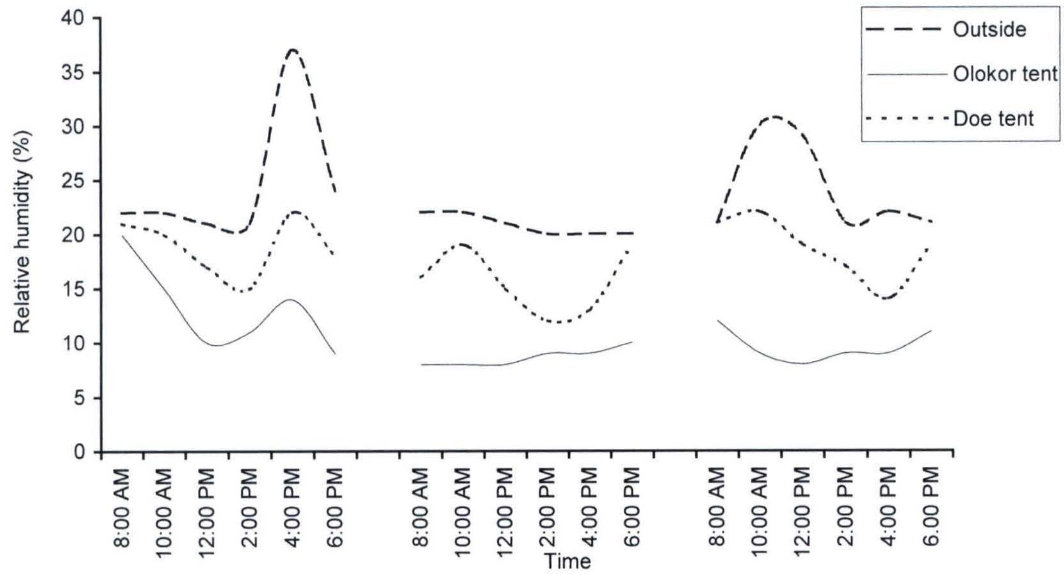


Figure 4.6 A: Relative humidity variation outside and inside solar dryers every 2 hours over a 3 day-period in March 2000

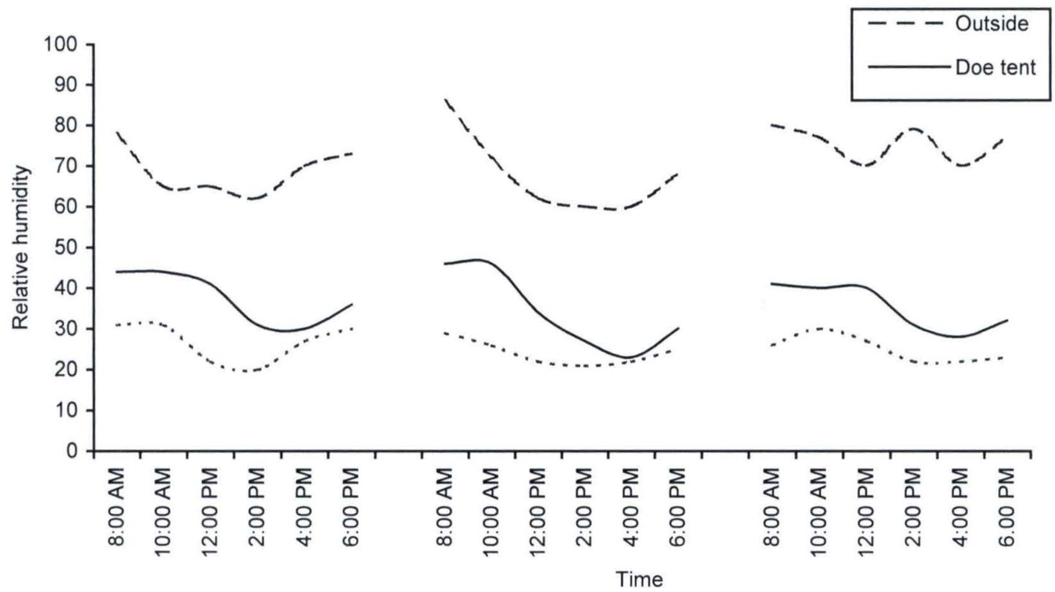


Figure 4.6 B: Relative humidity variation outside and inside solar dryers every 2 hours over a 3 day-period in August 2000

Table 4.6 ANOVA results showing significant differences ($P < 0.05$) in relative humidity inside and outside solar dryers

	March 1999	August 1999	March 2000	August 2000
Olokor Tent Doe Tent	P=0.00	P=2.132E-08 or P= $2.132x10^{-8}$ P= 0.00	P=3.985E-08 or P=$3.985x10^{-8}$ P = 0.00	P=3.779E-06 or P=$3.66x10^{-22}$ P = 0.00
Olokor Tent Outside	P=5.39E-09 P=$5.39x10^{-9}$ P=0.00	P=1.15E-24 or P=$1.15x10^{-24}$ P=0.00	P=3.02E-08 or P=$3.02x10^{-8}$ P=0.00	P=3.66E-22 or P=$3.66x10^{-22}$ P=0.00

Relative humidity was most significantly different between Doe tent and Olokor dryer in August of 1999 and least significant in March of 1999. It was persistently significantly different with ambient conditions throughout the trials.

4.2.3.3 Impact of Meteorological parameters on Weight Loss of Fish

As has already been acknowledged by previous studies such as those of Trim and Curran (1983), Doe *et al.* (1977, 1999), Jason (1988), Eyo (2001) and others, the primary principles behind the sun drying of fish using traditional open sun methods or solar dryers are meteorological. Thus, it requires a proper understanding of the working of these principles to obtain better and faster drying. The physics behind the natural drying of fish is the interplay of temperature, relative humidity, sunshine duration, and radiation and wind speed. Previous studies took these parameters into consideration while calculating drying rates (see Chapter 2). Attempt is made in this study to correlate all these parameters and see their individual impact on the rate of fish drying using fish weight data from the Olokor solar dryer.

Table 4.8 shows meteorological data collected during the period of fish drying trials in 1999 and 2000. These are shown against weight loss of fish in the solar dryer for the given day. The interaction between weight loss and the meteorological parameters are clearly shown in Figures 4.7 and 4.8. Figure 4.7 shows weight loss of fish rising and falling along with prevailing meteorological parameters from one season to another. It can be seen that, in March and August 1999 and 2000 meteorological parameters obtained outside the solar dryer were consistent with weight loss of fish inside the dryer. The line graph shows that weight loss pattern follow variability in the meteorological parameters.

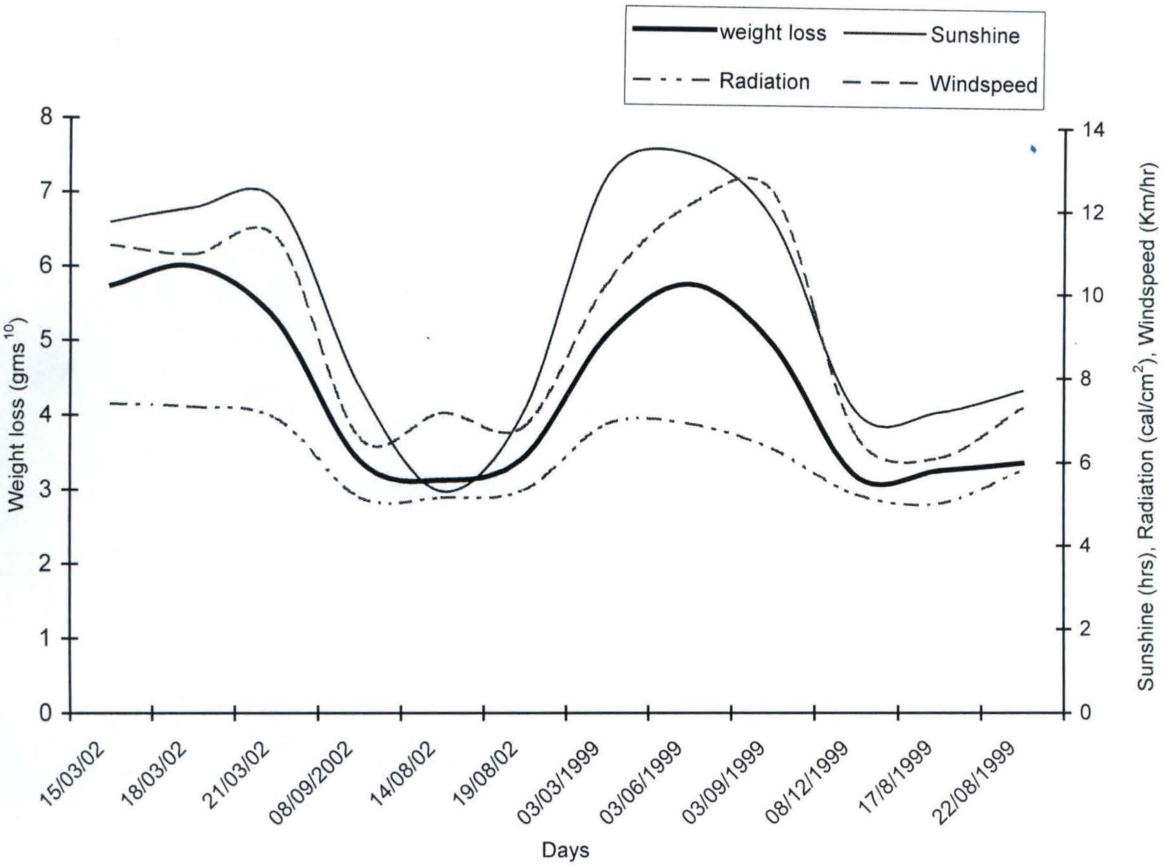


Figure 4.7: Relationship between weight loss, Sunshine, Radiation and Windspeed.

Figure 4.8 is a typical hourly pattern of meteorological parameters obtained at the drying site within a day. It shows that fish weight loss varies not only within seasons but also within the day. The extractive forces of the solar dryer are stronger by mid-day to late afternoons. This time was observed on the field as the period when weight loss is highest. Figure 4.8 shows weight loss increasing from 8am to a peak between 2-4pm when radiation, sunshine and temperature are highest and relative humidity lowest.

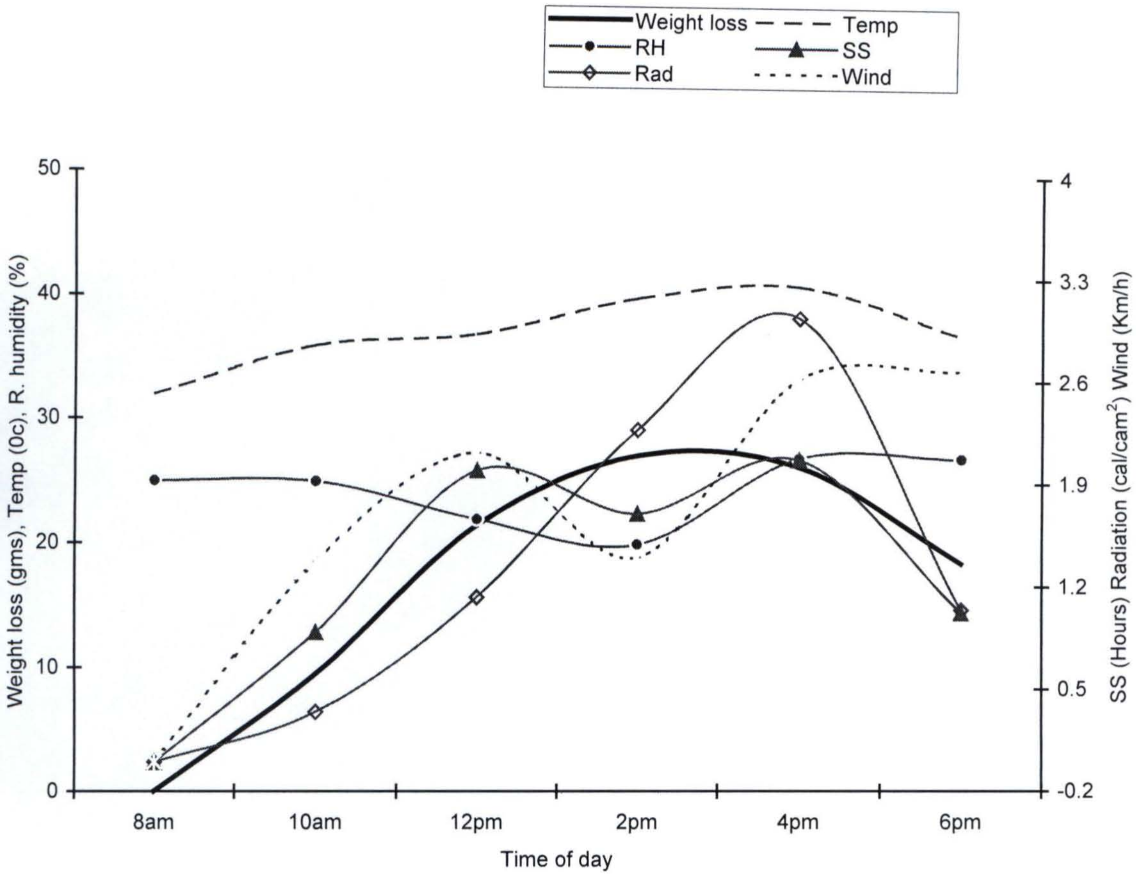


Figure 4.8 Hourly fluctuation in weight loss and metrological parameters affecting fish drying

Correlation analyses (Table 4.7) show that relative humidity had the highest relationship though inverse (r=-0.974) followed by radiation (r=0.970). The least, but still strong, is temperature (r=0.944). This shows that meteorological parameters are the primary determinants for fish drying either in the open sun or within the solar dryer, since weight loss during drying follow the pattern of these parameters

Table 4.7 Correlation coefficients between weight loss and meteorological parameters

	Temperature	Rel. Humidity	Sunshine	Radiation	Wind speed
Weight loss	R= +0.944	r= -0.974	r=+0.944	r=+0.970	r=+0.945

Table 4.8 Meteorological data obtained near drying site and Percentage weight loss of fish inside solar dryer in March and August 1999 and 2000

Days 3-day intervals	Weight loss %	Temperature °C	Relative Humidity %	Sunshine duration Hours	Radiation Cal/cm^2	Windspeed Km/hour
15/03/20	57.4	38.1	24.5	6.6	7.27	11
18/03/20	60.1	38.1	20.8	6.8	7.21	10.8
21/03/20	52.8	37	29	6.9	6.95	11.2
9/08/20	38.1	31	68.8	4.4	5.1	6.5
14/08/20	35.5	31.8	68	3	5.1	7.1
19/08/20	38.7	32	75.5	4.1	5.3	6.8
3/03/99	51.2	36.8	24.8	7.3	6.86	10.2
6/03/99	58.2	36.8	21.5	7.6	6.88	12.1
9/03/99	50.1	36.8	32.1	6.7	6.29	12.4
12/08/99	36.3	31.8	67.8	4.1	5.22	6.6
17/08/99	37.1	28.3	71	4.1	5.01	6.1
22/08/99	38.2	30.8	77.1	4.4	5.81	7.3

4.3.0. Percentage Weight Loss Of Fish inside solar dryer

4.3.1 Experiment 1 (Dry salted fish)

Figure 4.9 shows weight loss of fish treated with dry salt, that were put in the solar dryer (Treatment A) and those spread in the open sun (treatment B). Results show that treatment A lost more weight, dropping from 749 gm to 641.6gm (14.4%) after 12 hours of drying compared to treatment B that decreased from 750gm to 670gm (10.7%) over the same period. The initial weight loss of fish after the first day drying is critical for its keeping quality and is a determinant of how well the drying went, since a high moisture content will encourage bacterial activity and hence spoilage. It was observed during this stage of drying, that treatment B was not as fresh as treatment A, because treatment A lost an appreciable amount of moisture in the short run compared to Treatment B. At the end of 36 hours of drying inside the solar dryer, treatment A lost a total of 426.93gm (57%) while treatment B lost a total of 330gm (44%).

4.3.2 Experiment 2 (Brined Fish)

Figure 4.10 shows weight loss for brined fish in the solar dryer (Treatment C) and brined fish in the open sun (Treatment D). After 12 hours of drying, treatment C lost a total of 88.7gm from 749gm (11.8%) compared to treatment D that lost 44.6gm from 750gm (6%). Again at the critical

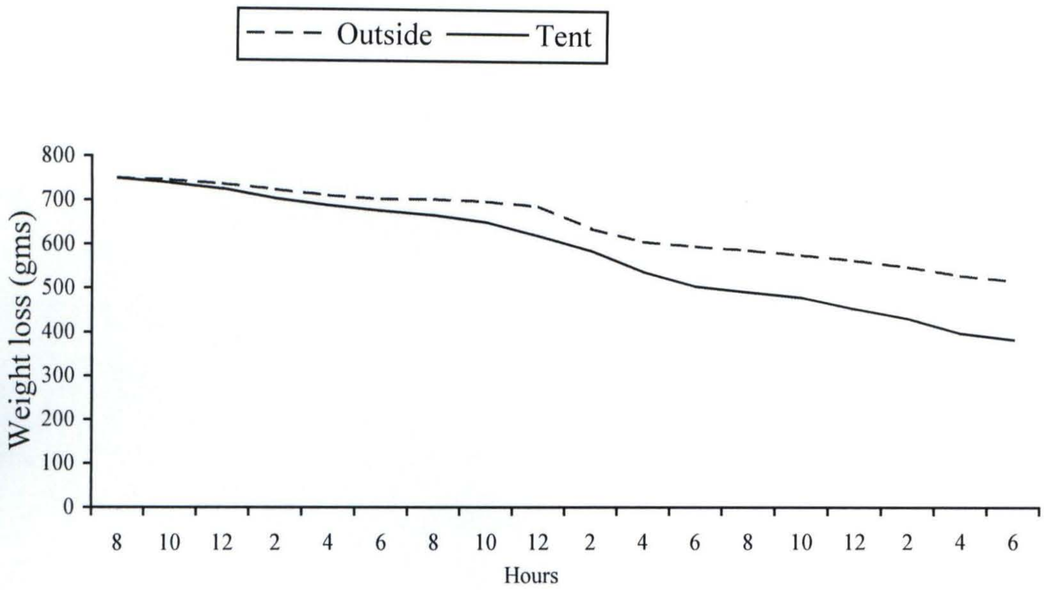


Figure 4.9: Weight of salted fish within and outside solar dryer over a 36 hours

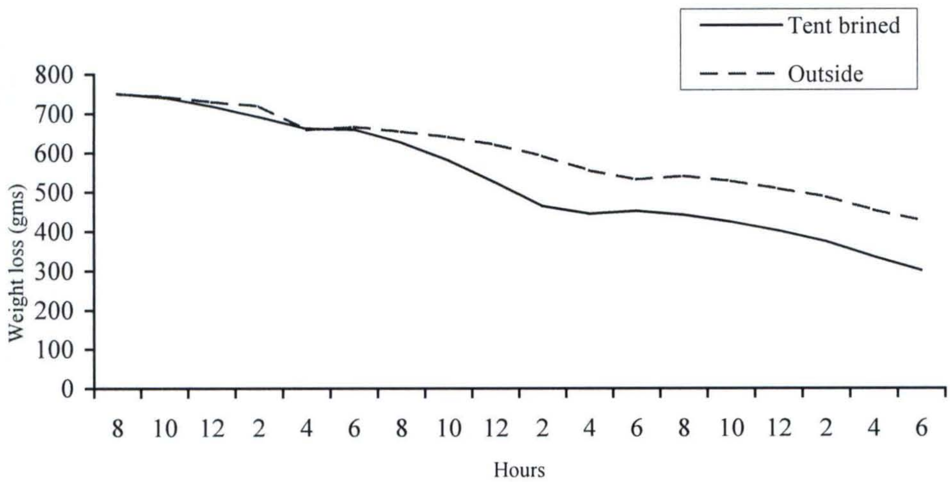


Figure 4.10: Weight loss of brined fish within and outside the solar tent dryer over a period of 36 hours

drying period, the fish inside the solar dryer (treatment C) lost more percentage moisture (48%) and giving it better chances of keeping quality compared to treatment D outside (30%) in the open sun. However, treatment E that had no salt treatment had a better initial weight loss (48%) than treatment B (Salted fish dried in the open sun) (44%), because of the impact of the solar dryer.

4.3.3 Experiment 3 (Unsalted Fish)

Figure 4.11 shows percentage weight loss for unsalted fish in the solar dryer (Treatment E) and fish dried in the open sun (Treatment F). After 12 hours of drying, treatment E lost a total of 91.9gm from 750gm (12.3%) compared to treatment F that lost 87.7gm from an initial of 750gm (11.3%). At the end of 36 hours, treatment E lost a total weight of 450gm (60%) while treatment F lost a total of 324gm (43%.).

Table 4.8 shows weight loss of fish with different treatments at 12 hours, 24 hours and 36 hours of drying periods inside the solar dryer. Previous studies of Trim and Curran (1983), Doe *et al.* (1977), Jason (1988) etc have shown that after 12 hours of drying, a weight loss below 10% is considered poor drying and has the likelihood of spoilage. The table shows that fish in the open sun without salt had the lowest weight loss of 6% after 12 hours of dryer in the sun. This falls below the critical initial weight loss of 10%. Other treatments in the open sun like treatment B (fish with salt) and treatment D, brined fish (fish soaked in concentrated salt water) had initial weight loss of 10.7% and 11.3% respectively.

This shows that salt helps facilitate drying as observed by previous studies. But brining fish with salt proves to facilitate drying more than just rubbing salt all over the fish as shown in the results.

It is remarkable to note that without salt on the fish, the solar dryer is able to facilitate the initial weight loss of fish above the critical drying level, thus proving the efficiency of the solar dryer. It raised weight loss of fish without salt to 11.8.% compared to its counterpart outside of 6%.

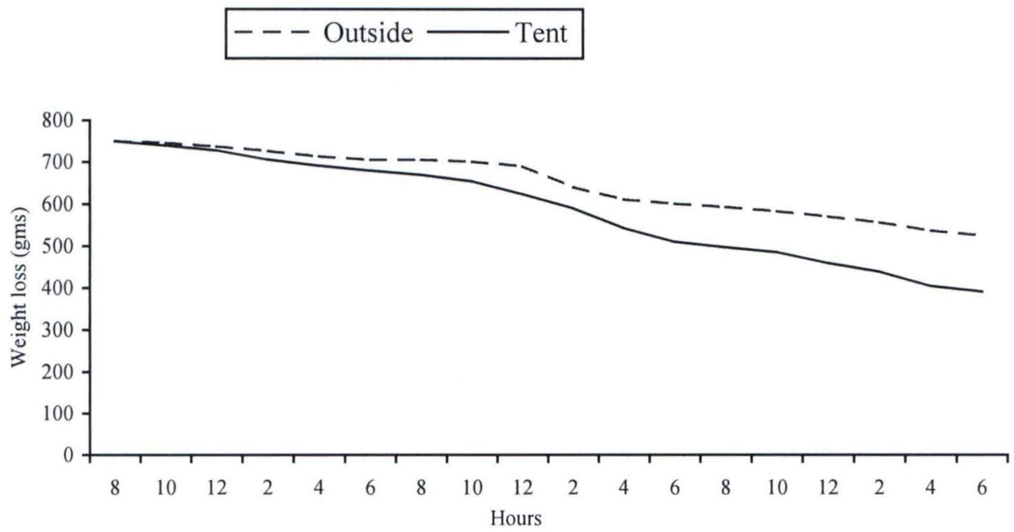


Figure 4.11: Weight of Unsalted fish within and outside solar dryer over 36 hours

Brining and salting of fish helped treatments B and D to attain a weight loss of 11.3% and 10.7% but fish processors' present practice does not entail the use of salt because of the cost of salt that will be required for commercial fish drying purposes. So the problem of fish spoilage by sun drying is likely to remain, except solar dryers are adopted.

The final moisture content of dried fish that enables it to store, is put at 10.7% or above 70% weight loss (Trim and Curran, 1983; Doe *et al.*, 1977; Jason, 1988). Table 4.9 shows that, the best final weight loss of fish was obtained by Treatment C (brined fish dried in the solar dryer), which had 60%. This is followed by Treatment A (salted fish dried in the solar dryer) with 57% and Treatment E (unsalted fish dried in the solar dryer) with 48%. All the fishes dried in the solar dryer, dried better than those outside. This confirms the efficiency of the solar dryer in fish preservation.

Table 4.9 weight loss of treated fishes over time inside and outside dryer

	Treatment A	Treatment B	Treatment C	Treatment D	Treatment E	Treatment F
Time	Tent Salted	Outside salted	Tent brined	Outside brined	Tent Plain	Outside Plain
8	749	750	750	750	749	750
10	739.5	742.3	740.1	742.3	739.4	746.1
12	718.02	723.7	718.2	729.1	727.1	737.7
2	685.62	704.5	690.4	718.7	705.7	726.4
4	664.14	685.5	660.7	658.2	691.1	713.1
6	641.6	670	658.1	665.3	660.3	705.4
Total	**107.4**	**80**	**91.9**	**84.7**	**88.7**	**44.6**
%loss	**14.4**	**10.7**	**12.3**	**11.3**	**11.8**	**6**
8	631.4	657.78	625.3	653.1	660	700.8
10	611.8	643.78	579.4	639.1	653.6	690.3
12	573	614.4	523.3	619.6	623	668.2
2	528.2	581.24	463.1	590.5	589.2	640.2
4	471.4	555.64	443.5	553.4	541.6	610.8
6	441.8	530.2	450.1	530.9	509.2	600.7
Total	**189.6**	**127.58**	**175.2**	**122.2**	**150.8**	**100.1**
%loss	**30**	**19.4**	**28**	**18.7**	**22.8**	**14.3**
8	426.8	520.5	440.3	539.1	495.9	592.8
10	406.8	515.3	422.4	526.1	484.6	582.4
12	382.3	495.5	400.3	506.5	458.7	570.3
2	357	460.7	372.7	486.3	437.2	556.2
4	325.6	429.5	334.1	452.6	403.5	536.8
6	322.07	420	300	425.1	389.5	525.1
Total	**104.73**	**100.5**	**140.3**	**114**	**106.4**	**67.7**
%loss	**24.5**	**19.3**	**31.9**	**21.2**	**21.5**	**11.4**
Grand Total	**426.93**	**330**	**450**	**324.9**	**359.5**	**224.9**
%	**57**	**44**	**60**	**43**	**48**	**30**

4.3.4. Pilot Trial of Solar Dryer in Eco-Zones of Nigeria

4.3.4.1 Weight Loss of fish inside solar Dryer

Table 4.10 shows weight loss of fish inside solar dryer in five Eco-zones of Nigeria during a pilot trial. The table shows that at the end of three days drying, weight loss of fish was lowest in Warri, (Forest Belt, latitude 5° 30′N), with a total of 204gm or 27.6%. This is followed by Ibadan (Wooded Savanna, latitude 7 ° 22′N) with a total weight loss of 329.5gm or 44%. New Bussa (Guinea Sudan, latitude 9 ° 51′N) was next with a total weight loss of 450.5gm or 60%. Fishes dried in the solar dryer in Jos (Sudan Sahel, latitude 9° 55′N) recorded a total weight loss of 411gm or 56% while in Baga north of Maiduguri (Sahel, Latitude 13° 10′N) total weight loss was 514.3gm or 63%. Weight loss decreased as latitude increased from the south to the extreme north of Nigeria, except for Jos due to lower ambient temperature. This is in accordance with the results of previous studies showing a strong correlation between latitude and radiation. The correlation between latitude and global radiation for instance was put at r = +0.80 (Kowal and Knabbe, 1972; Udo and Aro, 1999). Correlation analyses using weight loss values from Table 4.5 show that latitude is strongly related (r =+0.96) to weight loss of fish inside the dryer while altitude had a weak relationship (r = +0.24) with weight loss. The table shows that New Bussa (Latitude 9 °.51^{0}N) with an altitude of 180m recorded more weight loss of fish than Jos (Latitude 9° 53′N) with an altitude of 1275m. This is likely due to cooler climate resulting from high altitude and frequent cloud cover experienced during the trial period in Jos. Despite its altitude, weight loss records in Jos, was better than those of Warri and Ibadan.

The detailed eco-zone trial of the developed solar dryer shall be a subject of future study when funds and time are made available for a more detailed study.

Table 4.10: Weight loss of fish in some towns of Nigeria

Time	Warri Month: Jan Alt.:23m Lat.5.30N Long.5.45E	Ibadan Month: Jan. Alt.: 315m Lat.7.23N Long.3.54E	New Bussa Month: March Alt.: 180m Lat.9.51N Long.4.29E	Jos Month: March Alt.: 1270m Lat.9.55N Long.8.54E	Baga Month: April Alt.:210m Lat.13.10N Long.14.09E
8	738	750	750	732	815
10	728.4	715.3	740.1	721.5	784.8
12	711.1	690.7	718.2	695.1	750.3
2	691.3	670.4	690.4	668.2	711.9
4	670.3	645.5	660.7	633.4	677.5
6	652	624.8	658.1	625.1	644.1
Total	**86**	**125.2**	**91.9**	**106.9**	**170.9**
%	**11.7**	**16.7**	**12.3**	**14.6**	**21**
8	651.7	621.4	625.3	613.7	621.3
10	641.1	604.1	579.4	593.2	600.4
12	612.5	579.3	523.3	572.1	554.1
2	595.3	551.2	463.1	541.8	500.3
4	584.4	521.7	443.5	489.1	458.7
6	581.1	496	450.1	458.3	413.1
Total	**70.6**	**125.4**	**175.2**	**155.4**	**208.2**
%	**10.8**	**20.1**	**28**	**25.3**	**33.5**
8	581.1	492.9	440.3	476.2	408.1
10	577.7	485.1	422.4	451.1	375.3
12	568.4	471.3	400.3	420.3	349.7
2	557.5	454.2	372.7	383.7	331.3
4	543.4	432.6	334.1	352.3	317.5
6	534	420.5	300	321	300.7
Total	**47.1**	**72.4**	**140.3**	**155.2**	**107.4**
%	**8.1**	**14.7**	**31.9**	**32.6**	**26.3**
Grand **Total**	**204**	**329.5**	**450**	**411**	**514.3**
%	**27.6**	**44**	**60**	**56**	**63**

4.4.0 Production of better quality fish using the Kainji solar dryer compared to traditional sun drying.

To meet the objective of the study which is intended to use the developed technology (Olokor solar dryer) to produce fish that is healthy, nutritious and palatable for consumption when compared to traditional sun dried fish, this section presents results of the organoleptic quality of sun dried and solar dryer fish, their microbial load and their proximate analyses.

4.4.1 Product physical Quality

Visual observation of the final dried products reveals that the solar dried fishes were of better quality compared to the traditional open sun dried fish. The texture was hard and well dried and the products had a pleasant odour. All the 3 treatments within the solar tent dryer were of a light, whitish, yellow colour, while those outside were dark orange, showing signs of rancidity. Sun dried products were of poor quality, because of the low initial temperature and high relative humidity. But the dryer provided suitable conditions for fast drying, which discouraged bacterial attack. However at the end of the drying session, sun dried fishes improved in quality though not comparable to the solar dried fishes. The fish, sun-dried in the open, was observed to have sand, dirt, dust and ants on them. But those inside the solar dryer were cleaner.

Table 9 shows an assessment by a panel of ten members. It shows that fish in the solar dryer scored a mean of 8.2 in terms of appearance, compared to 5.2

for open sun dried fishes. Fishes in the solar dryer scored 7.8 in terms of texture compared to 6.6 for sun-dried fishes. In terms of odour, fishes in solar dryer scored 8.2 while those in open sun scored 4.6. For taste, the fishes in solar dryer scored 8.4 while those in the open sun scored zero because no member was willing to taste it due to its foul smell. The results show preference for solar dried fish. At 5% significance level Analyses of Variance shows that there was a significant difference ($p < 0.05$), P= 0.03 between both treatments.

Table 4.11 Organoleptic assessment of fish inside and outside solar dryer

Organoleptic Quality	Solar dryer (Mean Score)	Sun drying (Mean Score)
Appearance	8.2	5.2
Texture	7.8	6.6
Odour	8.2	4.6
Taste	8.4	-

4.4.2 Assessment of microbial load

Table 4.12 shows that fish dried in the open sun which is the fisherman's practice has the highest concentration of micro organism and thus less suitable for consumption. This is because it underwent spoilage due to poor drying resulting from ambient conditions. This indicates the need for solar dryer which improves ambient conditions as could be seen from the table where samples from the solar tent dryer had the least average microbes of 43.3 cfu/gm compared to 132 cfu/gm of open sun dried fish. Fresh fish recorded 64.3 cfu/gm numbers of microbes.

Table 4.12: Microbial assessment (cfu/gm) of sun dried fish and solar dried fish.

	Petri-dish	Petri-dish	Petri-dish	Average
Sample	**1**	**2**	**3**	
Open sun dried fish	162	163	71	132
Fish in solar dryer	79	39	12	43.3
Fresh fish	137	49	8	64.3

4.4.3 Percentage proximate analyses

Results of the proximate analyses composition shows that moisture content of fish in the solar dryer was reduced to 10.6% compared to 22.26% for fish dried in the open sun. The low moisture content of solar dried fish makes it more resistant to bacterial attack compared to open sun-dried fish as shown previously. Table 4.13 shows that fresh fish is made up of 78.96% water and the dryer was able to bring this down to 10.6%.

Table 4.13: Percentage analyses of fresh, sun dried and solar dryer fish

Sample identification	%moisture content	%Either extract	%crude fiber	%crude protein	Nitrogen free extract
Fresh fish	78.96	0.35	1.40	21.74	Nil
Fish inside dryer	10.60	8.46	0.40	82.14	Nil
Fish dried in open sun	22.26	16.25	0.72	62.3	Nil

The level of protein in the three samples shows that fish dried in the sun or solar dryer has more percentage crude protein than fresh fish. Fresh fish had 21.74%, fish in the dryer had 82.14% and fish outside had 62.3%. Thus solar dried fish is more proteinous than fresh fish or those dried in the open sun. The table further shows that open sun-dried fish had more fat (ether extract) of 16.25% compared to 8.46% of fish in the dryer and 0.35% of fresh fish. The high percentage ether extract of sun dried fish results from its poor drying process leading to rancidity. Analysis of variance shows that there was a significant difference in both qualities of fish (P = 0.003) at 5% significant level. These results from proximate analyses confirm that fish dried in the Olokor dryer is healthier and more nutritious than the one sun-dried.

4.5.0 Fuel Wood Consumption and Deforestation Rates Around Kainji Lake

In order to meet the objective of this section of the study, an attempt is made to relate the amount of fuel wood used for fish smoking to possible deforestation around Kainji Lake Basin. Questionnaires were administered to fish smokers in four major fishing villages as discussed in Chapter 3. Satellite imageries in conjunction with GIS and ground truth were used to estimate forest loss between 1976 / 1978 and 1993 / 1995. In this section the result of these studies are discussed.

The species of wood available to the fish processors at the four locations are shown in Table 4.14. The woods were all got from the forest around Kainji Lake. A total number of eleven species were identified and recorded. Kiria (ironwood), Taura (*Deterium microcarpum*), Dorowa (*Parkia clappertoniania*) and Maje (*Danielli Oliveri*) were preferred best in 60% of the villages because of their good smoke and fast rate of fish drying. This is similar to the findings of Eyo (1985). Least preference was given to Kade (*Butryospermum paradoxium*) and Roba (*Heavier Brazilinsis*) because of their black smoke.

Table 4.14 Wood species used for smoking fish in four fishing communities

Local Name (Hausa)	Botanical / common name
Kiria	Iron wood
Maje	*Danielli Oliveri.*
Roba	Heavier Brazilinsis
Kade or Kandenya	*Butryospermum paradoxium*
Sakania	*Botrychium Ivnana*
Marike	African red wood
Rini	*Adasonia spp.*
Balige	Roman tree
Taura	*Deterium microcarpum*
Dorowa	*Parkia clappertoniania*
Kolo	*Pterocarpus angolensis*

Table 4.15 shows the projected cost and quantity of wood and fish on a daily, weekly and yearly basis using 76 fish processors. The results obtained show that the total weight of woods used at the four sites on a daily, weekly and yearly basis are 1,250kg, 7501kg and 396,250kg respectively going by 6 days of smoking in a week and 317 in a year. The average cost of wood incurred on a daily, weekly and yearly basis is ₦4,180, ₦25,080 and ₦1,325,060 respectively. On a daily, weekly and yearly basis in the sampled sites 599kg, 3593kg and 189,883kg of fish were smoked. Finally, On a daily, weekly and yearly basis in the sampled sites, ₦60,800, ₦ 364,800 and ₦19,273,600 worth of fish were smoked respectively.

Table 4.15: Summary of daily, weekly and annual amount and cost of fuel wood / fish smoked by 76 fish processors

Quantity of wood	Amount
Quantity of wood / person /day	16.45kg
Cost of wood / person / day	₦ 55
Quantity of fish / person /day	7.88kg
Cost of fish / person / day	₦800
Quantity of wood /76 resp./day	1250kg
Cost of wood / day	₦4180
Quantity of fish / day	599kg
Cost of fish / day	₦60, 800
Quantity of wood / week	7501kg
Cost of wood / week	₦ 25,080
Quantity of fish / week	3593kg
Cost of fish / week	₦ 364,800
Quantity of wood / year	396,250kg
Cost of wood / year	₦ 1,325,060
Quantity of fish / year	189,883kg
Cost of fish / year.	₦19, 273,600

Observation in the field shows that only small trees of 25cm to 50cm circumference are felled for fuel wood. Larger trees are considered too difficult and uneconomical to fell unless those that are dead and dried. Calculation from this study show that each fish processor consumes 16.45kg of fuel wood or 7.5m^2 forest wood per day compared to 0.46m^2 given as the average by FAO (1985). This depicts the high rate of forest wood consumption per person around the Kainji Lake Basin. This implies very high rate of deforestation arising from high demand of fuel wood for fish smoking. If the solar dryer adapted for this study becomes popular among fish processors in the Kainji Lake Basin, it can reduce significantly the pressure on local forests arising from the high demand on fuel wood for fish smoking. Especially when studies already show that there are no significant differences in both smoked fish and those dried with the solar dryer (Amadi, 2000).

Amadi (2000) carried out organoleptic tests for fish dried inside the Olokor Dryer and fish smoked with wood. His results show that there are no significant differences (P>0.05) in odour, appearance and taste of both smoked fish and solar dried fish (See Appendix B).

It is expected that with a little effort at advertising the new technology in the study area, both fish processors and consumers are likely to easily adopt the dryer and accept the product respectively.

Table 4.16: Deforestation rates around Kainji Lake

Vegetation type	1976 / 1978	1993 / 1995	Magnitude of change	% increase	% decrease	Remark
Forest plantation	3,393.8	1,978.2	1,415.6	-	41.7	Decreased
Undisturbed forest	181.1	-	181.8	-	100	Erased
Grasses	775	118.8	656.2	-	84.7	Decreased

Source: Ikusemoran, 2000

Forestland decreased from 3,393.8km^2 in 1976 / 1978 to 1,415.6km^2 in 1993 / 1995, a percentage decrease of 41.7%. The satellite maps (Figures C2 and C3 in Appendix C) show that this change is more pronounced on the eastern part of the lake than on the western part. This is because the western part is protected by law as part of the Kainji Lake National Park. Particularly affected, as can be seen from Table 4.16, is the undisturbed forest, which in 1976 / 1978 was 181.1km^2 but got completely wiped out by 1993 / 1995. This can be attributed to a rising human population around the Kainji Lake, which with increasing demand for fuel wood and wood for other purposes had led to extinguishing the undisturbed forest.

Grasses accounted for 775km^2 of the entire lake area in 1976 / 1978. This area was reduced to 118.8km^2 in 1993 / 1995. Although no form of grass charring of fish is done around Kainji Lake, this change reflects a growing population of livestock and farmers who require more space for their livelihood. Almost all the fishermen keep herds as well as own a farm.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

Kainji Lake is the largest man made lake in Nigeria. The Lake Basin is rich in diverse aquatic and terrestrial resources. Since the lake is a major fish basket of Nigeria, fuel wood requirement for fish smoking is very high. In the course of this study, a solar dryer was designed to offer fish processors around Kainji Lake basin an alternative or compliment to fish smoking using fuel wood. Since the high demand for fuel wood in the area has severe implications for local forests and contribute to greenhouse gas emission in general.

5.2 Summary

Solar energy is a renewable resource that is abundant in Nigeria. Although fish processors have realized the need to utilize this energy source around Kainji, their practices are be-set with numerous shortcomings. Hence a solar dryer was designed to improve their drying practices. The solar dryer was an improvement of an earlier design first used in Bangladesh in 1977. Both new and old designs are similar in shape and size, but the new design has black rocks as its solar absorbers. It is this singular innovation, which makes the major difference in the performance of the old design and the new, because the black rocks helped to generate and conserve radiant energy inside the dryer. The old design had no rocks but had black polyethylene sheet as absorbers. The new dryer was able to keep away insect and other pests from the fish during the drying process and had numerous advantages that made fish processors in the villages to prefer it. Temperatures were much higher in the new design than in the old one and relative humidity were much reduced in the new one compared to the old design. Temperature and relative humidity conditions were also better in the new design than ambient conditions where local fish processors dry their fish.

Traditionally sun dried and solar dryer fishes were subjected to laboratory analyses. The fish in the solar dryer had an average of only 43.3 microbes cfu/gm, while fish dried in the open sun had an average of 132.0 microbes cfu/gm. Fishes dried in the solar dryer had more protein and less fat than those dried in the open sun. Fish processors were able to see for themselves that the new methods introduced to them using the solar dryer had more advantages than their own methods. The solar dryer, apart from being more efficient, produced healthier and more nutritious fishes, free from sand, stones and dusts. The adjustable drying racks and access zip on the dryer made fish drying relatively easy. Fish processors could conveniently spread their fishes to dry while they go to farms without fear of rain, insect or animal pests.

There has been a high demand for the newly designed solar dryer. Enquries have been made across the country and from abroad. During the course of the study, the dryer was tested in some towns across five eco-zones the country to be able to advice potential users on the possible efficiency levels of the solar dryer in their geographical locations. Latitude was chosen as the primary criterion and the dryer was tried in different latitudes from 4^0 N to 13^0 N. The observed weight loss of fish in the dryer for Warri, latitude 5^0 30' N, was 204 gm in 36 hours. This increased northwards to 329.5gm or 44% at Ibadan while at New Bussa latitude 9^0 51'N the weight loss further increased to 450.5gm or 60% over 36 hours. At Jos (latitude 9^0 55' N) weight loss of fish inside the solar dryer was 411gm or 56% while at the extreme north of Nigeria at Baga (latitude 13^0 10' N) weight loss was 514.3gm or 63%. These weight losses show that fish drying is more enhanced as one moves northwards because weather conditions are more favourable.

Four major fish smoking villages were studied to determine the amount of fuel wood used for fish smoking. This study has revealed that fish smoking around Kainji Lake is very intensive. Over 396, 250kg of forest wood are used to smoke fish around that lake annually. This amounts to ₦1, 325,060 worth of fuel wood, which is used to smoke fish worth N19, 273,800 annually. This findings show that on the average each fish processor consumes 16.45kg of fuel wood or 7.5m^3 of forest wood a day compared to 0.46m^3 estimated for tropical countries by previous studies. To further confirm these findings, satellite imageries for 1976 /1978 and 1993 /1995 were studied to show difference in forest cover. Outcomes of the analyses showed that the forestland of the basin decreased from 3,393.8km^2 in 1976 /1978 to 1978.21km^2 in 1993 / 1995, a total reduction of 63.9% through factors including fish smoking.

5.3 Conclusions

Based on all the findings from the studies conducted in the course of this work, the following conclusions can be reached:

a. The newly designed solar tent fish dryer (Olokor type) was as cheap and simple as the Doe type.

b. The Olokor type was however more efficient and cleaner than both the Doe type and local fish processors' practices. And as Werner Schmidt GTZ Fisheries Expert puts it in AT Magazine (See appendix E):

   " I'm always coming across 'new inventions', which are said to dry fish cleanly, quickly and cheaply. But many haven't convinced me. Either they don't work or are too expensive to produce. But I am really impressed by this method. The trick here lies in the use of black stones"

   Fish processors around Kainji and Jebba lakes have easily adopted the Olokor type of dryer because of its simplicity and efficiency. It has equally gained attention from the press such as NTA television, Newspapers and Magazine features. Also, government decision makers such as ministers of agriculture, directors of research institutes and parastatals have requested for its use.

c. The Olokor fish dryer produced better dried fishes than the open sun drying methods of fish processors. Fishes from the solar dryer were more nutritious (with higher proteins and less fat) and healthier.

d. Solar dried fish resembles the imported stockfish very closely in terms of colour, appearance and taste. Thus dried fish should enhance the economic status of local fish processors by increasing the prices for their fish produces.
e. The solar dryer performed best in the northern parts of Nigeria and least in the southern parts. Its performance increases from the coast northwards.
f. The study also shows that the Kainji Lake National Park as a vital tourist attraction with its wealth of animal and plant resources is being highly deforested due possibly to high fuel wood consumption for fish smoking.

5.4 Recommendations and Suggestions for Further Research

During the course of this study numerous shortcomings and ideas were identified. Coupled with the experiences gained during field data collection, the following recommendations are suggested:

a. The Olokor type of dryer is recommended for fish processors involved in sun drying of fish around Kainji, Jebba and Lake Chad areas.
b. Since areas around the coastal parts of Southern Nigeria have no rocks required to construct the dryer, cement slabs or sand are recommended instead. However, this suggestion requires further trials.
c. The designed dryer requires further improvements especially as regards its portability. The dryer has other shortcomings observed by users in

the field such as its small holding capacity and susceptibility to wind displacement.

d. The fish from solar dryer needs to be subjected to different expert cooking trials so as to come out with the most palatable methods. Because of the scope of the study, much emphasis was not given to this area and other areas in pure fisheries or chemistry. Experience shows that soaking in cold water before introducing to soup had better taste than soaking in hot water.
e. There is need for a rigorous campaign by governmental and interested agencies on the need to patronize locally produced goods such as the solar-dried fish.

At present the demand for solar dried fish product is low but with good marketing research and advertisements it can compete with the imported stockfish. The local fish processors have expressed their reservations about the demand for local sun dried fish and are willing to go into commercial production of solar-dried fish if there is a viable market for it. Since there is such market presently for smoked fish they have preferred smoking to drying using solar dryer. Thus, government needs to give a helping hand to propagate this new product to shift some attention from smoking to drying in order to conserve forest and reduce greenhouse gas emission.

This was the case when Dr. Jonah Madugu former minister of state for agriculture requested all the 36 states ADP to own and use at least one of the Olokor solar dryers. Further encouragements like this are required from government.

f. Going by the current rates of deforestation around Kainji Lake, there is need to carry out aforestation schemes to replace cut down trees. If the current trend of deforestation continues the area is likely to experience desertification, erosion and other attendant problems resulting from deforestation.

g. There is need, however, to carry out specific research on the contribution of fuel wood consumption for fish smoking as a source of forest removal compared to other sources such as lumbering, agriculture, industrialization and other human activities.

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APPENDIX A

CLIMATE DATA OF KAINJI LAKE BASIN

Table A1 : Mean Monthly hours of Sunshine for New Bussa

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN
1985	6.6	7.5	6.7	8.9	8.7	6.9	6.4	5.3	6.1	8.1	8.0	8.5	7.31
1986	8.8	8.4	8.7	7.8	8.4	8.5	5.8	6.0	7.0	6.6	9.3	8.5	7.82
1987	7.4	7.2	3.9	6.8	8.3	7.9	7.2	4.5	6.9		9.8	8.9	6.57
1988	9.2	9.8	8.0	7.4	8.7	7.9	5.1	5.2	7.1	7.9	9.1	9.0	7.87
1989	8.0	9.8	6.4	8.1	7.6	7.5	6.0	5.5	6.7	9.0	8.1	8.3	7.58
1990	8.8	8.6	8.3	7.2	7.2	8.2	6.0	6.5	8.3	8.6	8.5	6.8	7.75
1991	8.3	7.9	7.5	7.8	6.8	7.7	7.2	6.6	7.4	8.6	6.7	9.4	7.66
1992	9.2	6.7	6.7	8.0	7.9	7.1	6.7	5.1	6.6	8.1	7.9	7.1	7.26
1993	3.2	8.0	6.9	8.0	8.2	7.1	6.8	6.0	7.1	7.0	8.7	8.3	7.11
1994	5.6	5.8	6.5	6.4	7.9	7.9	6.9	7.7	7.0	6.1	6.9	5.7	6.7
1995	6.7	5.8	3.0	5.2	7.2	7.5	6.3	6.9		7.8	9.3	5.1	5.9
1996	7.2	8.4	6.3	6.4	7.4	8.6	5.1	5.9	7.6	8.9	8.9	6.9	7.3
1997	7.1	7.9	6.5	6.4	8.8	8.0	7.5	6.6	7.4	8.3	8.7	6.1	7.44
1998	8.7	7.8	6.5	7.9	6.4	7.3	5.6	5.6	7.3	7.9	8.5	8.0	7.29
1999	6.2	8.4	6.4	8.1	7.5	7.7	5.8	4.7	6.1	8.6	7.5	8.9	7.16

Source: NIFFR Climate Data Base

Table A2: Mean Monthly Rainfall (in mm) for Yauri

Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1951	0	0	0	7.62	190.5	117.1	322.1	154	324.9	117.9	0	0	1234.43
1952	0	0	0	303	117.35	22.37	145.8	191	177.3	106	0	0	1063.05
1953	0	28.5	18.8	18.54	260.86	58.42	297.2	55.9	269.5	99.46	0	0	1107.08
1954	0	0	5.08	10.92	127.76	161.3	172.2	346	231.9	73.15	0.25	0	1128.51
1955	0	0	11.7	8.38	111.51	91.69	311.4	219	255.3	124.2	0	0	1133.6
1956	0	0	13	0.76	57.66	147.6	167.6	338	238	96.01	0	0.51	1059.43
1957	0	0	8.38	60.96	121.41	183.1	190.5	194	195.7	80.01	0	0	1034.15
1958	0	1.02	0	19.05	166.88	160.5	192.5	56.1	283	75.95	0	0	955.09
1959	0	117	16.5	20.32	101.6	122.9	229.6	407	265.9	44.7	0	0	1325.38
1960	0	0	0.25	60.96	92.2	203	262.6	162	258.6	69.08	0	0	1108.45
1961	0	0	0	16.26	66.8	204.5	285	178	248.9	0	0	0	999.25
1962	0	0	0.51	75.44	137.92	216.9	108.9	341	286.8	163.3	16.51	0	1346.89
1963	0	1.79	1.27	69.34	93.98	174	172.7	420	235	117.4	0	0	1285.76
1964	0	0	0	20.07	122.94	226.6	179.1	295	295.6	2.03	0	0	1141.21
1965	0	15.8	0	21.37	100.58	199.1	140.7	289	187	0.25	0	0	953.56
1966	0	0	0	23.88	150.37	186.7	104.4	209	0	0	0	0	674.12
1967	0	0	0	0	0	0	0	203	181.9	28.96	0	0	413.77
1969	0	0	0	38.61	122.68	189.2	228.6	187	176.5	99.82	3.81	0	1045.97
1970	13	0	4.52	32.26	29.72	71.63	178.8	309	259.3	73.15	0	0	971.25
1971	0	0	6.86	0.25	93.98	161	122.9	335	235.5	32.77	0	0	987.82
1972	0	0	3	25.2	123.8	164.3	165.7	225	214.2	18.5	0	0	939.7
1973	0	0	0	42.7	11.3	98.5	151.7	306	157.9	45.9	0	0	813.5
1974	0	0	0.3	18.7	60.5	174.5	431.4	113	252.1	39.2	0	0	1089.8
1975	0	0	0	37.6	81.7	157.8	252.7	225	187.1	31	0	0	973
1976	0	0	0	1.3	174.5	96.6	150.9	201	121.8	135.4	6.9	0	888.8
1977	2	0	8.1	0	65.2	132.9	187.9	263	168.4	36.6	0	0	864.3
1978	0	0	51.3	96.5	154.4	112.9	98.2	140	174.7	59.1	0	0	887.4
1979	0	0	0	74.9	69.2	187	189.2	302	128.1	56.5	7.2	0	1014.4
1980	0	0	4.1	40.6	127.8	69.6	213.5	247	152.1	24.3	0	0	879.2
1981	0	0	1	22.3	84.9	116.6	387.9	184	98.7	0.4	0	0	895.9
1982	0	0	74.6	74.9	98.5	92.2	199.7	345	144	42.8	0	0	1071.6
1983	0	0	40	11.4	124.3	59.3	128.9	137	102.6	0	0	0	603.5
1984	0	0	22.1	33.3	190	137.1	157.6	229	181.6	19.9	0	0	970.5
1985	0	0	42.2	0	39.7	86.4	283.7	170	160.1	10.3	0	0	792.7
1986	0	0	5.8	13.9	23	165.1	216	228	289.9	66.9	0	0	1008.2
1987	0	0	6.2	0	32.8	156.4	155.7	212	146.4	37.3	0	0	746.5
1988	0	0	0	41.4	36.7	216.5	149.8	385	111.3	1.5	0	0	942.3
1989	0	0	0	0	76.5	194.7	271.2	103	180.9	78.2	0	1.9	906.2
1990	0	0	0	40.6	76.6	82.6	198.7	158	195.1	0.4	0	0	751.9
1991	0	0	3.4	82.2	239.3	256.6	216.4	139	100.5	70	0	0	1107.2
1992	0	0	0	0.2	139.5	125.4	206.4	310	246.9	17.1	0	0	1045.9
1993	0	0	3.4	9.9	153.8	126.3	272.6	116	153.9	90.6	0	0	926.1

Source: NIFFR Climate Data Base

Table A3 : Mean Annual Rainfall (in mm) for Kainji Dam site New Bussa

YEAR	TOTAL
1969	1193.03
1970	789.7
1971	1093.73
1972	897.63
1973	910.07
1974	939.29
1975	889.76
1976	815.33
1977	871.23
1978	938.02
1979	1133.59
1980	1001.19
1981	963.14
1982	1034.84
1983	639.68
1984	1048.25
1985	980.4
1986	1026.75
1987	949.09
1988	858.79
1989	1178.89
1990	1181.16
1991	1285.29
1992	752.88
1993	1015.48
1994	1578.4
1995	1282.2
1996	1219.2
1997	1542.4
1998	1593.2
1999	1646.8

Source: NIFFR Climate Data Base

Table A4 : Mean Monthly Wind Speed (in km) for Yauri

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN
80	86.78	95.94	102.56	162.75	160.75	133.26	128.86	105.12	86.33	83.17	64.69	59.93	105.8
81	72.89	88.36	120.53	126.76	171.51	156.00	138.20	105.50	81.80	66.10	60.80	76.00	105.4
82	81.40	72.20	106.50	132.20	131.43	120.00	118.20	88.40	73.80	85.00	61.60	60.00	94.23
83	71.50	73.20	104.80	140.20	139.60	99.50	90.10	84.70	69.70	87.60	59.00	69.50	90.78
84	65.20	64.31	100.80	134.70	134.10	119.10	97.61	76.50	65.00	78.20	66.10	74.80	89.7
85	73.94	79.10	97.19	136.74	133.45	122.78	90.73	82.10	76.30	74.40	68.80	60.26	91.32
86	89.30	95.98	93.20	135.60	135.30	125.01	105.20	84.40	73.20	74.90	51.80	50.50	92.87
87	74.38	86.70	106.60	98.40	136.90	116.01	101.90	83.65	71.60	57.10	55.00	53.94	86.85
88	63.30	80.80	86.50	115.30	107.20	86.70	67.80	50.50	35.80	25.10	32.30	35.70	65.58
89	44.20	62.80	49.88	57.80	77.07	46.90	60.70	77.60	82.20	62.90	67.00	70.30	63.28
90	68.00	69.50	106.40	160.90	151.52	141.62	107.87	85.33	76.78	61.59	57.30	70.09	96.41
91	69.60	70.04	104.66	102.71	152.24	118.04	101.19	84.30	73.20	60.60	55.50	60.47	87.71
92	72.49	90.52	96.37	138.81	148.11	109.94	93.01	69.40	55.88	44.40	49.39	58.71	85.59
93	71.45	42.74	51.33	133.24	77.08	79.72	24.41	18.57	13.64	9.52	10.15	22.70	46.21

Source: NIFFR Climate Data Base

Table A5: Mean Monthly Maximum and Minimum Temperatures (in ^{o} c) for New Bussa

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN
XIMUM	33.6	36.5	37.8	36.1	33.4	31.3	29.8	29.8	30.9	31.1	34.5	35.5	33.4
IMUM	15.3	22.0	24.6	24.8	23.1	22.4	22.4	22.4	22.4	22.1	18.6	14.5	21.2
XIMUM	35.3	36.4	37.5	38.9	34.9	32.2	31.8	29.3	30.9	32.9	36.6	34.8	34.3
IMUM	17.1	19.1	22.6	26.9	26.4	23.6	23.8	22.9	22.9	21.4	14.9	14.1	21.3
XIMUM	35.7	38.5	37.3	35.3	33.5	32.5	30.5	30.4	30.6	33.1	33.9	35.7	33.9
IMUM	15.2	18.8	23.9	26.1	24.4	23.4	22.7	22.5	21.8	22.7	17.5	14.7	21.1
XIMUM	36.4	37.5	38.4	37.7	34.4	31.7	30.7	30.5	30.8	33.4	36.0	34.3	34.3
IMUM	16.6	17.9	25.3	26.5	25.6	23.4	22.6	23.0	22.2	22.1	19.5	15.0	21.6
XIMUM	31.6	37.1	38.6	38.6	33.4	32.8	30.8	30.5	32.1	33.7	36.5	16.1	32.7
IMUM	17.5	19.5	24.1	27.2	24.5	23.9	22.9	22.7	22.5	23.1	70.0	62.0	30.0
XIMUM	33.5	37.6	38.8	38.4	34.3	33.5	30.3	30.8	31.4	34.6	36.0	36.0	34.6
IMUM	14.7	19.3	23.9	26.0	25.4	24.5	22.7	22.9	22.6	22.5	17.9	14.1	21.4
XIMUM	34.2	35.4	37.7	37.3	34.9	32.5	31.0	29.7	31.2	32.5	35.2	35.3	33.9
NIMUM	16.1	20.7	24.3	26.6	25.6	24.0	23.1	22.4	22.4	22.4	16.6	14.3	21.5
XIMUM	31.1	38.0	38.3	39.1	36.1	33.1	31.7	30.5	31.9	36.3	37.7	35.9	35.0
NIMUM	15.4	20.1	22.3	26.4	25.2	24.5	23.4	23.0	22.8	21.3	17.3	17.0	21.6
XIMUM	34.5	37.1	39.4	37.6	33.6	32.4	31.3	32.0	30.9	33.8	36.9	34.1	34.5
NIMUM	15.8	18.9	25.3	27.0	24.3	23.4	22.3	22.5	21.8	22.8	18.3	15.0	21.5
XIMUM	36.6	36.5	38.9	38.5	36.6	33.1	30.7	30.7	31.2	34.7	37.4	33.6	34.9
NIMUM	17.5	17.9	25.7	26.8	26.4	24.2	22.3	22.3	22.0	20.9	16.6	15.4	21.5
XIMUM	34.7	38.8	38.3	38.4	37.1	33.6	30.5	30.6	30.7	33.5	34.9	33.4	34.5
NIMUM	14.6	19.3	25.1	28.0	26.8	24.1	22.8	22.4	22.0	21.9	18.0	13.7	21.6
XIMUM	36.0	38.3	38.9	40.7	38.6	33.6	32.4	31.5	32.3	34.3	37.8	36.1	35.9
NIMUM	15.3	18.7	23.5	25.4	27.5	24.2	23.8	23.3	23.0	22.1	16.5	15.8	21.6
XIMUM	34.2	37.9	40.4	38.0	37.3	32.7	31.4	29.8	31.1	35.6	37.2	33.5	34.9
NIMUM	17.9	20.4	25.9	27.1	27.2	23.8	23.6	21.8	22.1	20.2	16.6	15.5	21.8
XIMUM	32.8	35.2	39.1	39.0	35.5	32.6	30.8	30.6	31.8	33.6	36.2	34.2	34.3
NIMUM	13.7	17.6	22.4	26.7	25.0	22.5	21.7	21.4	21.0	19.5	15.3	14.5	20.1
AXIMUM	35.7	36.3	39.3	39.1	34.5	33.9	31.0	31.2	32.0	34.3	36.4	36.5	35.0
NIMUM	17.1	18.4	21.5	26.7	25.3	24.6	22.7	22.4	21.6	21.7	19.0	19.1	21.7
AXIMUM	35.3	38.1	38.8	37.5	32.8	31.4	29.9	29.8	31.7	32.8	35.8	33.9	34.0
INIMUM	17.5	22.9	25.3	26.8	24.7	23.8	23.0	32.1	22.6	22.6	16.7	15.2	22.8
AXIMUM	33.0	36.7	39.2	39.0	34.5	31.9	30.3	29.6	30.4	32.9	34.8	34.7	33.9
INIMUM	16.0	18.3	24.3	26.7	25.0	23.1	22.2	22.1	21.6	22.0	17.8	15.2	21.2
AXIMUM	32.5	37.3	38.4	40.0	37.3	33.1	31.2	30.6	31.4	34.5	34.4	35.8	34.7
INIMUM	15.3	18.3	23.3	25.4	24.8	23.4	21.8	22.6	22.0	23.1	22.5	19.0	21.8

Source: NIFFR Climate Data Base

Table A6 : Mean Monthly Relative Humidity (%) for New Bussa

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN
82	71	82	67	69	88	92	99	98	95	91	85	64	83.42
83	61	46	89	65	79	95	90	98	95	93	63	59	77.75
84	57	57	90	88	83	91	95	95	95	93	76	48	80.67
85	55	50	63	79	85	90	95	96	95	84	80	58	77.5
86	65	80	68	96	96	95	95	97	88	84	70	62	83
87	50	59	61	80	94	86	98	98	90	85	66	54	76.75
89	57	73	73	72	86	84	97	96	89	90	69	59	78.75
990	45	58	86	69	88	92	92	100	94	79	66	61	77.5
991	44	38	73	84	86	88	96	99	94	85	76	60	76.92
992	65	56	79	86	80	86	95	95	94	81	70	61	79
993	63	59	74	77	90	90	100	100	100	89	84	64	82.5
994	58	77	68	67	90	97	86	94	93	91	58	72	79.25
995	65	58	70	99	72	86	98	99	96	79	69	55	78.83
996	43	65	66	74	99	93	94	94	96	86	66	88	80.33
997	63	56	52	80	86	84	98	96	94	75	70	74	77.33
998	45	61	78	80	96	94	95	98	92	89	77	58	80.25
999	41	49	63	77	91	91	96	97	92	87	75	65	77

Source: NIFFR Climate Data Base

APPENDIX B

DATA ON SOLAR DRYING

Table B1 : Materials and Cost of Constructing the Olokor Dryer

Materials	Number	Cost N per unit	Total N
Polythene Sheet	10 yards	100	1000
Wire mesh	2 yards	130	260
Kuralon rope	4 yards	20	100
2"x2" wood	1	120	120
Transportation of Rocks	40 pieces	400	400
Sewing of Polythene tent	1	500	500
Cost of making drying rack	1	200	200
Black Paint	1	120	120
Sticks	5	Free	Free
Cloth screen	1 yard	100	100
Im Zip	1	100	100
Total			**2,900**

Table B2 : Materials and Cost of Constructing the Doe Dryer

Materials	**Number**	**Cost N per unit**	**Total N**
Polythene Sheet	10 yards	100	1000
Wire mesh	2 yards	130	260
Kuralon rope	4 yards	20	100
2"x2" wood	1	120	120
Black PVC Polythene Sheet	3 yards	150	450
Cost of making drying rack	1	200	200
Mounting of polythene sheets with pins		300	300
Sticks	5	Free	Free
Total			**2,430**

Table B3: Materials and Cost for Constructing a Typical drum Smoking Kiln

Material	Quantity	Cost N
176 litre empty drum container	1	1200
2" Wire Mesh	1 yard	130
¼ iron rod	1 length	420
Construction of Kiln	1	500
Total		**2,250**

Source: Amadi (2000)

Table B4: Organoleptic Assessment showing no significant differences in Odour of solar dried fish (Using Olokor Dryer) and Fish smoked with wood

Solar Dryer	9	9	5	8	6	3	6	3	6	8
Drum Kiln	8	6	8	6	8	8	6	8	8	8

Source: Amadi (2000)

P=0.166968

Table B5: Organoleptic Assessment showing no significant differences in Appearance of solar dried fish (Using Olokor Dryer) and Fish smoked with wood

Solar Dryer	9	9	6	6	6	6	6	9	9	8
Drum Kiln	9	8	8	8	8	6	3	6	6	8

Source:Amadi (2000)

P=0.592137

Table B6: Organoleptic Assessment showing no significant differences in taste of solar dried fish (Using Olokor Dryer) and Fish smoked with wood

Solar Dryer	8	6	8	8	8	6	6	8	6	6
Drum Kiln	6	8	6	6	9	8	6	6	8	8

Source: Amadi (2000)

P=0.845075

APPENDIX C

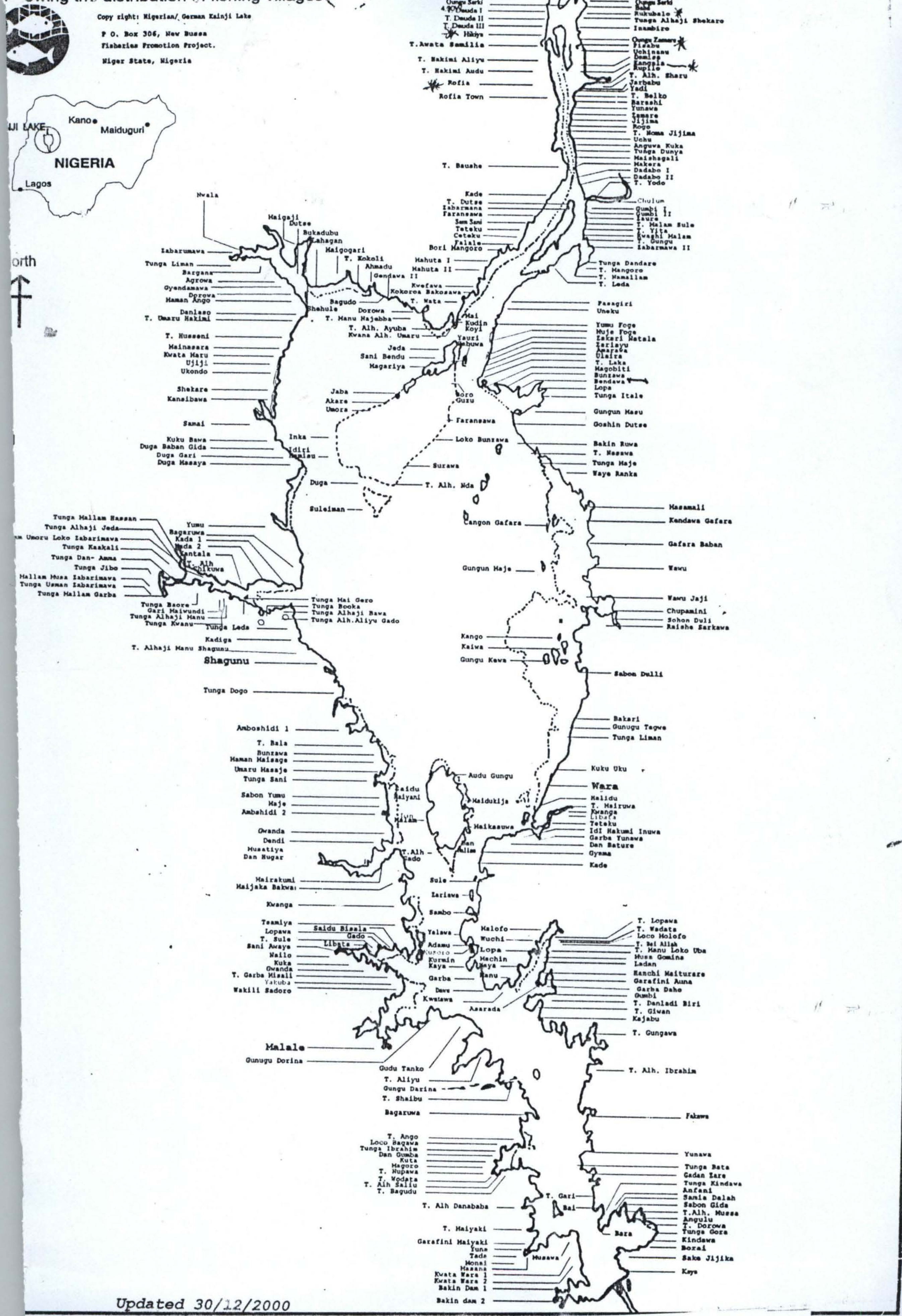
SATELLITE IMAGERIES AND MAPS

OF KAINJI LAKE BASIN

Kainji Lake, Northern Nigeria.

Showing the distribution of fishing villages

P O. Box 306, New Bussa
Fisheries Promotion Project.
Niger State, Nigeria



Updated 30/12/2000

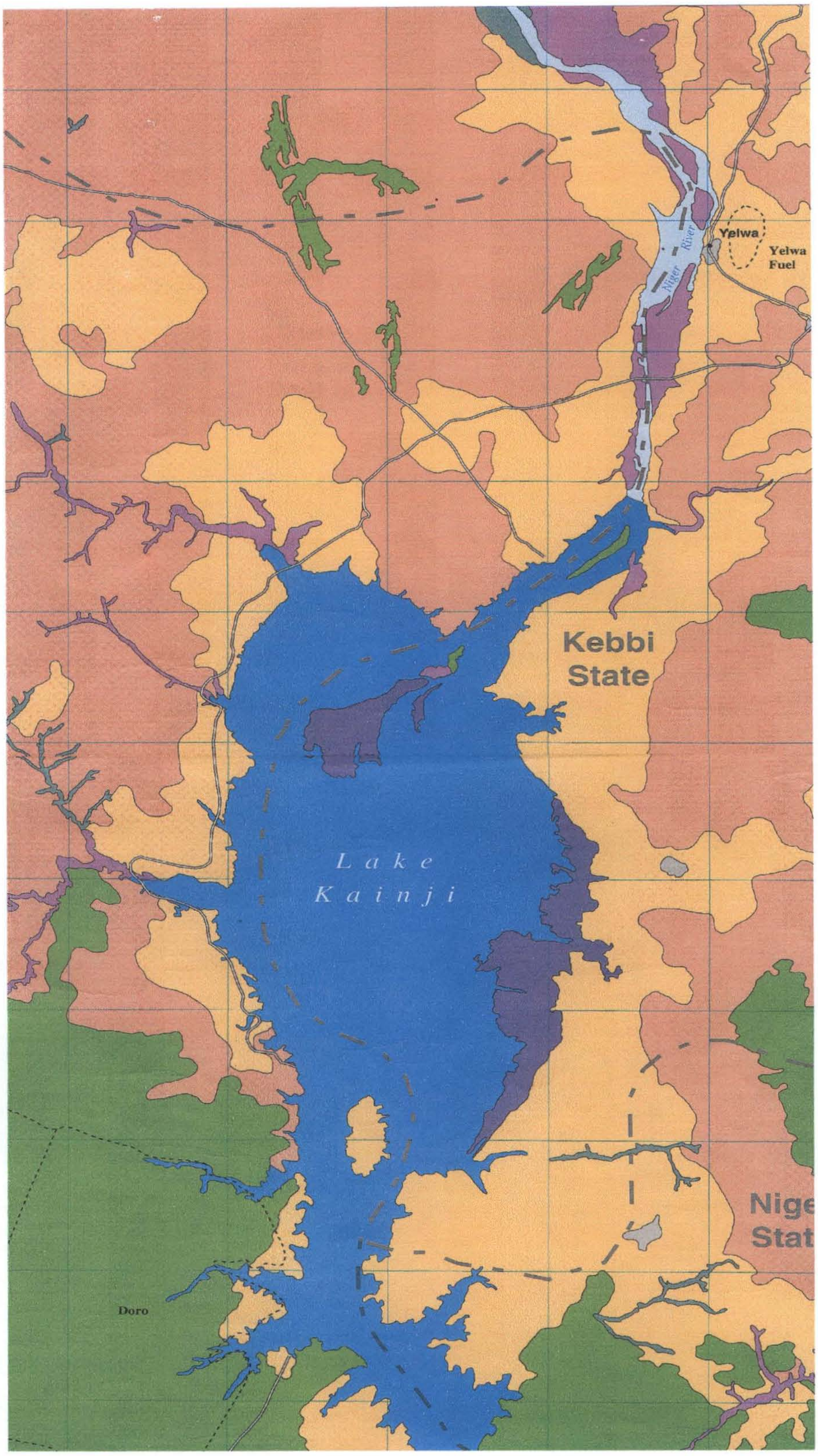


Fig C3: 1976/1978 LANDSAT MSS and SPOT XS Image of Kainji Lake

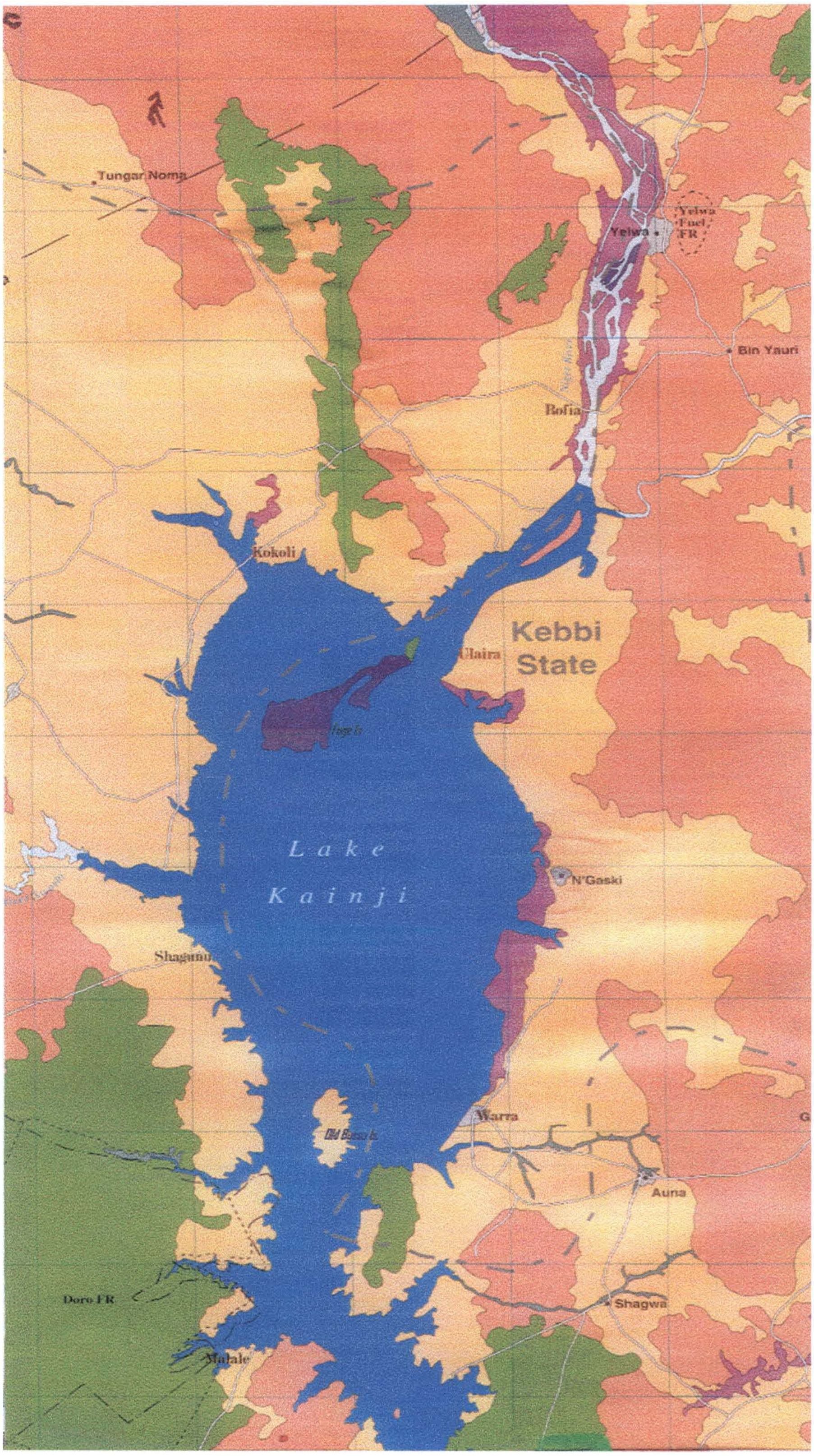


Fig C4: 1993/1995 LANDSAT MSS and SPOT XS Image of Kainji Lake

APPENDIX D

CONSTRUCTION OF SOLAR DRYERS

Plate X: Explaining the working of the solar tent to the Village Head of Monai and GTZ project Adviser

Plate ix: Fish processors sampling their product

Plate x: Cutting sticks to construct solar dryers in a fishing village

Plate xi: Gathering sticks to construct solar dryers in a fishing village

Plate xii: Gathering rocks to construct solar dryers in fishing villages

Plate xiii: Fish processors sharing rocks for communal solar dryers

Plate xiv: Arranging rocks to build a solar dryer in a fisherman's compound

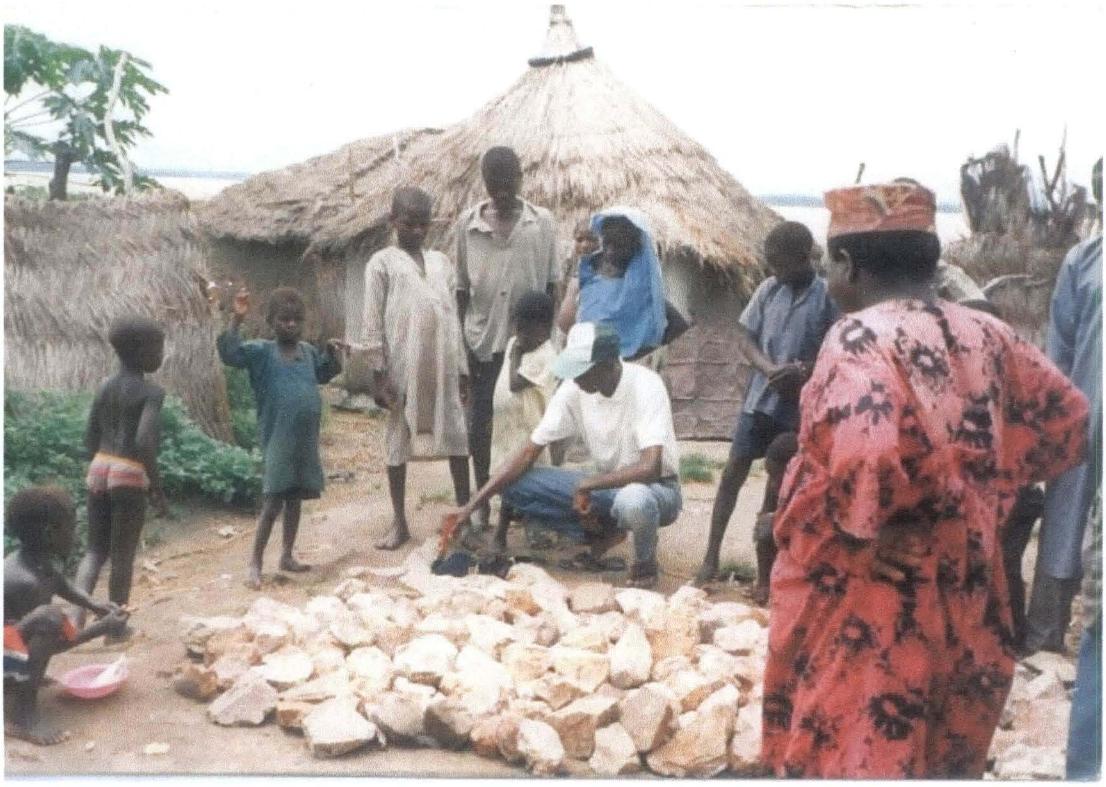


Plate xv: Painting of rocks black with local dye in fishing villages

Plate xvi: Teaching fish processors how to gut and salt fish in a fishing village

Plate xvii: Solar tent dryer at Gbajibo village, Jebba Lake

Plate xviii: Fisherman presented with a solar tent dryer

Plate xix: Fishermen at Yauri admiring solar dried fish