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Analysis of Health Aspects, Food Acceptability and Econc Benefits of the Solar Box Cooker in Sierra Leone

October 1, 1988 - May 31, 1990

Final Report

Contractor
Southern University & A & M College
Contract Number: DAN - 5053-G-SS-8029-00

Principal Investigator
Barbara W. Carpenter, Ph.D.

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Leroy Davis, Ph.D.
John Moland Jr., Ph.D.
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TABLE OF CONTENTS

INTRODUCTION

The Solar Box Cooker (SBC) Project was initiated in January 1989 at the Institute of Agricultural Research, Njala, Sierra Leone through the auspices of Southern University, Baton Rouge, Louisiana.

The SBC has been used in some parts of the world for cooking and pasteurizing water. It is an attractive innovation particularly in developing countries where wood is used for cooking and forests are being destroyed in obtaining wood thus threatening the environment and the economics of some countries. However, like any new technology there is need to ensure appreciable adoption if the effort is to be worthwhile. Consequently, considerable work was needed in the areas of recipe development and the use of local materials for construction to ascertain positive adoption in Sierra Leone.

OBJECTIVES OF THE PROJECT

Generally, the project was aimed at ascertaining the effectiveness of the SBC as an instrument for cooking and pasteurizing water, as well as, the degree to which it and its products are acceptable to the people of Sierra Leone.

Specific Objectives were as follows:

1) To ascertain the extent of reduction of pathogenic micro-organism of foods cooked and water pasteurized via the solar box cooker in the village environment.

2) To determine the acceptability of solar box cooked food as compared with foods via the traditional methods.

3) To estimate the costs savings of fuel and labor for foods cooked via the solar box cooker.

4) Adopt Solar Box Cooker technology for successful use in a designated developing country.

Logistical Set-Up

The Project operated under the auspices of the Institute of Agricultural Research (IAR) which has its headquarter at Njala University College in Sierra Leone and operated in five zones in the country each with a zonal headquarter. Each zone covers an area with a ten miles radius from the zonal headquarters which are each located at Njala, Kabala, Makeni, Rokupr and Kenema. These zones cover the various, geographic ethnic and socio-cultural divisions of the country. Technologies developed at Njala are disseminated to other parts of the country through these zones. This structure has been intensively utilized in reaching the people. The institute was previously the Adapted Crop Research and Extension Station (ACRE).

The IAR nutrition laboratory was used for recipe development and partly for the water pasteurization activities in conjunction with the analytical laboratory. The construction of solar boxes from locally produced materials was initiated at the Institute's carpentry workshop. The IAR also provided temporary office space and its vehicles were used for travelling to the zones for monitoring demonstrations and other related activities.

Project Activities

The activities undertaken were aimed at presenting the technology as an attractive proposition to the target group. Much emphasis was placed on the cooking aspect of the solar box cooker. However, the other activities which included water pasteurization and the estimation of costs savings of fuel wood ran concurrently.

ERADICATION OF PATHOGENIC MICRO-ORGANISM IN FOODS

Various pathogenic micro-organisms have been shown to occur in certain food stuffs some of which could cause serious diseases if not eradicated. Most times, however, these organisms are destroyed when the food is properly cooked. This investigation was aimed at ascertaining the extent of the reduction of such pathogenic micro-organisms in foods cooked via the SBC.

Methodology

Some of the usual items used in preparing foods were bought at the Njala market and samples were obtained from them. These samples were cultured on potato dextrous agar for three days after which the fungi contained therein were identified. These food stuffs were separately placed in the SBC and also used to prepare certain dishes.

The products were removed after 4 hours 30 minutes from the Solar Box Cooker and samples were obtained from these

and cultured for three days. They were then tested for the presence or absence of the organisms earlier detected. Each sample was replicated 4 times.

Results

Table 1 shows that with the exception of the onions and smoked fish, all the other raw products contained different types of fungi. Among the products, pepper was shown to contain the highest number of fungi. It can also be seen that all the identified fungi were killed after the products had been cooked in the SBC.

The SBC can effectively destroy the usual fungi associated with food stuffs.

TABLE 1: Effect of Solar Box Cooker on Fungi Associated with Food Products.

	FOODSTUFF	RAW FUNGI IDENTIFIED	COOKED
1.	Onions	Nil	Nil
2.	Pepper	Rhizopus sp.	"
		Aspergillus sp.	"
		Penicillium sp.	"
		Cercospora sp.	"
		Curvularia sp.	"
		Colletotrichum sp.	"
3.	Fish (smoked)	Nil	"
4.	Groundnut paste	Rhizopus sp.	"
		Aspergillus sp.	"
5.	Sweet potato leaves	-	"
6.	Groundnut soup	-	"
7.	Palm oil soup	-	"

WATER PASTEURIZATION

There are three basic sources of drinking water in the rural areas, shallow hand-dug wells with a large diameter, concrete lining and a cover, the deep tube wells and the gravity fed systems and spring boxes. Except in the case of tube wells, bacteriological contamination of the water provided is a major concern for all these sources.

Since the vast majority of Sierra Leoneans live in the rural areas, the SBC Project has sought to investigate the adaptation of the cooker for use in sterilizing drinking water samples. The method is simple and on a "good" day requires about 5 hours of sunshine. Factors such as type of container and turbidity of the sample have been shown to significantly influence the results.

The majority of rural people are not immediately aware of the necessity of water treatment. Usually a sample of water is considered drinkable from only an aesthetic point of view. People are only aware of the debilitating manifestations of water-borne diseases but not of the presence of the causative agents as these are invisible. Efforts to eradicate these water-borne diseases must include educating the users of any new technology in the need for and effectiveness of the measure in question.

Methodology

The process of water pasteurization investigated was simply to place litres of water in an open container in the SBC which had been placed in the sun for about 30 minutes. The temperature was usually about 120c by the time of introducting the sample. Samples were withdrawn at hourly intervals and tested for coliforms and E-coli with the Colilert Test System. Similar quantities of water were placed alongside the box, one covered and the other uncovered. The three set samples was subjected to the same test procedure.

Results

Tables 2 and 3 (a) and (b) show the results obtained in the experiements described above for each source (well, tap, swamp or river). The total sterilization time is indicated (1, 2, or 3 hours).

Total coliforms were completely destroyed after 1 hour of treatment of the well water. No E. coli growth was observed in the raw water. The tap and swamp water required 2 hours and the river more than 3 hours.

Table 3a shows that solar irradiation alone also sterilizes polluted water after 2 hours (well) and 3 hours (tap, swamp and river). These sources were probably more heavily contaminated with total coliforms as well as E. coli. When the water sample was not covered (Table 3b) the

total coliforms detection showed that little destruction took place. Since the days were quite sunny and the experiments were conducted in the same area, the samples must have been polluted from the air. The E. coli (not being airborne) counts were similar to the other tables.

Conclusions

The Solar Box Cooker SBC can be used to disinfect small quantities of water for drinking purposes. The quantity of water used in these experiments was small, typically 2- 3 litres at a time. The main constraint at this time was the size of the cooker. Increasing the quantity of water is a desirable goal in the light of these results.

TABLE 2: Effectiveness of SBC in Water Disinfection using a Presence (+) Absence (-) "Collilert" Method

Source	Well		Tap		Swamp		River	
	1	2	1	2	1	2	1	2
Raw Water		-		-		+		+
	+	-	+	-	+	+	+	+
	+	-	+	+	+	+	+	+
	+	-	+	+	+	+	+	+
	+	-	+	+	+	+	+	+
1st Hour	-	-	+	-	-	-	-	+
	-	-	-	-	+	-	+	-
	-	-	-	-	-	+	+	+
	-	-	-	-	-	-	+	-
	-	-	+	-	+	-	+	-
2nd Hour	-	-	-	-	-	-	+	+
	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	+	+
	+	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-
3rd Hour	-	-	-	-	-	-	+	-
	-	-	+	-	-	-	-	-
	-	-	-	-	-	-	-	-
	-	-	+	-	+	-	+	+
	-	-	-	-	-	-	-	-

1 and 2 refer to total coliforms and E. coli respectively.

\+ = present

\- = absent

TABLE 3a: Effectiveness of Solar Irradiation in Water Disinfection (a) Water Covered with Clean Plastic Sheet Spread over the Container.

Source	Well		Tap		Swamp		River	
	1	2	1	2	1	2	1	2
Raw Water		-		-		+		+
	+	-	+	-	+	-	+	+
	+	-	-	+	+	-	+	+
	+	-	+	-	+	-	+	+
	+	-	+	+	+	-	+	+
1st Hour	+	-	+	-	+	-	+	+
	+	+	+	-	+	+	+	-
	-	-	+	-	+	-	+	+
	+	-	+	-	+	+	+	+
	-	-	+	-	+	-	+	-
2nd Hour	-	-	-	-	-	-	+	+
	-	-	-	-	-	-	+	-
	-	-	+	-	+	-	+	+
	+	-	+	-	+	-	+	-
	-	-	-	-	-	+	-	-
3rd Hour	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-
	-	-	-	-	+	-	-	-
	-	-	-	-	-	-	-	-

1 and 2 refer to total coliforms and E. coli respectively.

\+ = present

\- = absent

TABLE 3b: Effectiveness of Solar Irradiation in Water Disinfection. (b) Water not Covered

Source	Well		Tap		Swamp		River	
	1	2	1	2	1	2	1	2
		-		-		+		+
Raw Water	+	-	+	-	+	-	+	+
	+	-	-	+	+	-	+	+
	+	-	+	-	+	-	+	+
	+	-	+	+	+	-	+	+
	+	-	+	+	+	-	+	+
1st Hour	+	-	+	-	+	-	+	+
	+	+	+	-	+	-	+	+
	-	-	+	-	+	-	+	+
	+	-	+	+	+	-	+	+
	-	-	+	-	+	-	+	+
2nd Hour	+	-	+	-	+	-	+	+
	+	-	+	-	+	-	+	+
	+	-	+	-	+	-	+	+
	+	+	+	+	+	+	+	-
	-	-	+	-	+	-	+	-
3rd Hour	-	-	-	-	-	-	+	+
	-	-	+	-	+	-	+	+
	+	-	+	-	+	-	+	-
	-	-	-	-	+	-	+	-
	+	-	-	+	+	+	+	-
4th Hour	-	-	-	-	+	-	+	-
	+	-	+	-	+	-	+	-
	+	-	-	-	+	-	-	-
	-	-	-	-	+	-	+	-

1 and 2 refer to total coliforms and E. Coli respectively.

\+ = present

\- = absent

EXTENT OF ACCEPTABILITY OF SOLAR BOX COOKED FOOD

A major concern for this investigation was whether food prepared using the SBC was as acceptable to people for eating as food prepared using the customary cooking methods. Eating is not simply a matter of satisfying the hunger drive and sustaining life, but it is also a very emotional personal experience. In addition to the nurtritional value received from eating food, eating also provides pleasure as well as security, cultural identity, and status. Whether a particular dish is consumed with satisfaction by an individual or group depends upon a number of factors, including cultural habits, social conditions, appearance, smell, and taste. Cultural practices related to the manner in which food is prepared, also affects one's willingness to eat the food as well as the satisfaction one derives from eating it.

Taste Test Methodology

Several taste tests are available for judging whether there is a difference between the taste of samples of food. The commonly used tests are the paired comparison, the triangle, and the duo-trio. The triangle test is the most widely used of all taste tests. The paired comparison and triangle tests were selected for use in this study. The paired comparison test involved presenting two samples of foods and asking judges questions about them, such as,

whether there was a difference of any kind between the two samples. The judges had a 50 percent chance of guessing correctly. The significance of these data can be determined by the use of a table or by statistical analysis.

The Triangle Test involved the presentation of three samples to judges with two of the samples as duplicates. Judges, as tasters, were asked to identify the odd sample. Given that they were asked to identify the odd sample out of three, it was possible to make three different selections, only one of which was correct. Therefore, the chance of guessing correctly was 33 percent, or once in every three trials. The significance of the data from a triangle test can be determined by statistical analysis or by the use of table.

The Problem and Hypothesis

The concern of this investigation is whether there is a difference between the taste of food cooked by the traditional method and food cooked by the SBC. Traditionally, food is prepared for cooking by firewood and while the food is cooking the pots are opened for stirring, seasoning, and adding other ingredients. Cooking by use of the SBC involves placing all of the ingredients, including seasoning, in the pot before it is placed in the SBC. The solar box is not opened for stirring and seasoning purposes.

Using the triangle experimental design, we wished to test the hypothesis that the proportion of odd samples correctly identified by the taste judges is not significantly different from (that is, below) the known proportion of .33 in the experiment. If this hypothesis is accepted it means the judges are able to differentiate between the food cooked using the traditional method and food cooked using the SBC. On the other hand, if the hypothesis is rejected it means the judges are unable to detect a difference between the taste of traditionally cooked food and solar box cooked food. In such a case, the number of correctly identified odd plates is significantly below the number in the experiment.

The Experiments and Findings

Triangle experiments were conducted at four different times using five or more judges on each occasion. The first experiment was conducted at the Agricultural Research Institute immediately after the completion of the construction of six SBCs on January 12, 1989. Various foods were prepared and cooked without previous experience or knowledge relative to preparing local foods for cooking in the solar box and the use of the solar box for the best results. The design for the triangle pre-test was developed for eight subjects with each person tasting three samples in three trials. Each trial consisted of either one sample cooked by the solar box and two cooked by the use of firewood or one

cooked by firewood and two by the SBC. One sample out of the three on each of the three trials was an odd sample (see Table 4) for details of the design and the food served in each sample).

Table 4: Design for eight Judges Tasting Three Sample in each of Three Trials.

Group I: Four Judges					
Trial 1.	Samples:	T	S	S	Rice and sweet potato leaves
Trial 2.	Samples:	S	T	T	Rice and pepper soup
Trial 3.	Samples:	T	S	T	Rice and groundnut soup
Group II: Four Judges					
Trial 1.	Samples:	S	S	T	Rice and sweet potato leave
Trial 2.	Samples:	S	T	S	Rice and pepper soup
Trial 3.	Samples:	T	T	S	Rice and groundnut soup

The eight judges were divided into two groups of four each and asked to identify the odd sample in each trial. Judges in each group tasted food from three samples in each of three trials. Thus, each judge tasted nine samples of food during the experiment, giving a total of 72 taste samples. Twenty-four of the 72 samples were odd samples. The eight judges correctly selected 18 odd samples from the total of 24. Thus, the correct selection was made 75 percent of the time. Utilizing the test of significance between two proportions and the null hypothesis of no difference between the number of odd samples correctly identified

and the number of odd samples present in the trials, the null hypothesis was not rejected. The computed z value of 1.44 was less than the value required to reject the null hypothesis at the .05 level of significance. Thus in the first experiment, judges were able to distinguish between food cooked by the traditional method and food cooked by the SBC. However, four judges made a total of six errors in identifying the odd plate (See Table 5).

Table 5 Triangle Taste Experiment

Exp. Number	Num. of Tri. Tastings	Total Num. of Tastings	Number of Dup. Tastings	Number of odd Tastings	Number Cor. Ident.	Z
1	24	72	48	24	18	1.44
2	24	72	48	24	13	2.71
3	15	45	30	15	7	2.42
4	54	162	108	54	33	3.52

The calculated value of Z must exceed 1.64 for significance at the 5% level, 2.33 for significance at the 1% level, and 3.09 at the level 0.1% level.

When the eight judges were asked which sample would you prefer to serve your family and friends, three indicated a preference for food cooked by the Solar Box Cooker on trial one; three a preference for Solar Box Cooker food on trial 2; and, on trial 3, all judges preferred serving food cooked by the traditional method to their family and friends. Some of the judges reported hard rice in one of the samples in trial 3 which was determined to be rice from the Solar Box

Cooker. It was established that two different varieties of rice were used in preparing the food and that one variety takes more water and longer to cook. In the traditional method of cooking, ingredients are added in a set sequence with occasional stirring of the mixture. Given this practice of opening pots while cooking, water can be added as needed. The fact that some varieties of rice take more water than others was not taken into consideration in preparing the pot for solar box cooking in this initial experiment. For cooking in the solar box, all ingredients are mixed together and then placed in the cooker which should remain closed until the food is done. Consequently, it was against this background that the project Director in Sierra Leone expressed great concern for testing the preparation of various foods and developing recipes for solar box cooking. Therefore, the Director and her nutrition staff at the Institute for Agricultural Research conducted a series of tests and prepared recipes for cooking all of the popular and frequently eaten local foods in the SBC.

Other taste experiments were conducted on February 22, 1989, May 16, 1989, and April 4, 1990. Table 6 provides the data and z values on all of the triangle taste experiments. The z values for the second and third experiments, 2.71, and 2.42, respectively, are greater than the critical value at the .01 level for a one-tail test and the z value for the fourth experiment, 3.52, is significant at the .001 level.

Given these z values, we reject the null hypothesis and conclude that the number of odd samples correctly identified by the taste judges is significantly below the actual number in the experimental design. Therefore, we accept the proposition that the judges were unable to distinguish between food cooked in the traditional manner and food cooked by the SBC.

Given that foods differ in terms of manner of preparation, seasoning, water, and cooking time, triangle taste experiments were conducted for a number of frequently and widely eaten foods. Table 6 presents triangle test findings for five types of frequently eaten foods prepared by the traditional and SBC methods.

Table 6. Triangle Taste Experiment for Five Types of Food Prepared by the Traditional and Solar Box Cooker Methods.

Type of Food	Num. of Triangle Tastings	Total Number of Tastings	Number of odd Tastings	Number Correctly Identified	Z
Ebbeh	12	36	12	9	1.02
FooFoo Okra Sauce	18	54	18	11	2.03
Groundnut & Rice Soup	12	36	12	6	2.05
One Pot Jollof rice	12	36	12	5	2.05
Pepper Soup	5	15	5	2	1.65

The calculated value of z must exceed 1.64 for significance at the 5% level.

The z values obtained for all but one type food (ebbeh) are significant at the .05 level or better. These findings indicate that with training and experience in the preparation of food using the SBC, as with any new cooking device, the difference in taste as compare to the usual method of cooking declines significantly.

In another experiment, judges were given samples of traditional and solar box cooked foods and asked the following questions.

1. How much do you like or dislike sample A? (Traditional)
2. How much do you like or dislike sample B? (Solar Box Cooker)
3. Which would you prefer to serve your family and friends?

The results indicated that there was not a significant difference between expressions of likes and dislikes for solar box cooked sample and sample of food prepared in the traditional manner. Neither was there any significant difference as to which sample one would prefer to serve family and friends.

Village Taste Panel

Following the successful preparation of the various dishes in the SBC and the triangle taste experiments conducted at the IAR, it was considered appropriate to conduct a taste panel survey on SBC foods in the five zones in which nutrition extension instructors worked under the former Adaptive Crop Research and Extension (ACRE) project and

which are still serviced by the Institute for Agricultural Research. The taste panel consisted of 5 persons from one village in each of the five zones, giving a total of 25 panelists. Eight products were prepared and presented for tasting. The panelists were asked to rate each product as very good, good, fair or poor as they found it. As shown in Table 7, a high percentage of the panelists rated rice and groundnut stew, cassava wheat cake, and banana bread as very good, the percentages were 50, 74, and 63, respectively. A similarly high percentage of the panelists, 54 percent for ebbeh and 51 percent for jollof rice, rated them as having a good taste. Cassava leaf sauce also received a favorable rating with 29 percent of the panelists rating it as very good while 37 and 31 percent rated it as good and fair, respectively. Thus, these six solar box cooked foods were rated as good to very good by more than two-thirds of the tasters.

Participants from the five villages were asked to compare the taste of foods cooked by the traditional and the solar box cooker methods. As shown in Table 8 four-fifths or more of the respondents from each village said the solar box cooked food tasted better than the traditional cooked food. All of the participants from the Taiama Village reported the solar box food as tasting better. Reasons given for the better taste included positive statements regarding smell, richness of flavor, and attractiveness of color. The

percentage of respondents that did not like the solar box cooked food ranged from zero to 20 percent in the different villages. A frequently given reason for not liking the solar box cooked food was "sun cooked foods are harmful to one's health" (See Table 8 for reasons.)

Respondents from the five villages were asked to give their reasons for liking or disliking the solar box as the means for preparing food (See Table 9). Reasons for liking the SBC were given by 60 to 100 percent of the respondents from the five villages. When responses one, two, and seven are combined, we find that the major responses given by respondents in all villages is "saves time". The SBC is viewed as economical: saving time, energy and money. Respondents from three of the villages gave as a reason for liking the SBC that the "food taste better." One hundred percent of the respondents from the village of Taiama indicated that they like the SBC and gave no reason for disliking it. Respondents from three villages (10 to 40 percent) said they disliked the SBC because it takes too long to cook their food. The solar box was unacceptable to 10 percent of the respondents from two villages, because they considered sun cooked food as harmful or as providing an opportunity for "one's enemies" to put something harmful in the food.

Eighty to 100 percent of the panelists in all villages would like to own a SBC (see Table 10). The time saving

economical aspects, including money and energy, were given as major reasons for wanting to own a SBC.

This study has demonstrated high preference for solar box cooked foods and high acceptability for personal ownership of a SBC. However, futher study is needed with respect to expanding recipe development and understanding attitudes toward using the solar box, particularly, the socio-cultural influences underlying attitudes against the use of the solar box for cooking purposes. In additon, program developments is needed for training in the use and diffusion of information regarding water pasteurization and cooking by means of the solar box.

Table 9: Reasons for Liking or Disliking the SBC

SBC Acceptability	Makami	Kabala	Rokupr	Njala Taiama	Njala Largo
Like the SBC.....	60%	90%	60%	100%	90%
Reasons for liking the SBC:					
1. Saves time from collecting wood.....	x	-	x	-	-
2. Economical, saves time and money.....	-	x	-	-	x
3. Easy to use, do not need to check on food frequently.....	-	x	-	x	x
4. Helps preserve the forest	x	-	-	-	-
5. Smokeless and not messy to cook with.....	x	-	x	-	-
6. Foods taste very good, better.....	x	-	-	x	x
7. Gives one time to do other things: relax, be with family, do other work....	x	x	-	x	-
8. Strange and interesting technology.....	-	-	-	x	-
9. Don't need to get married at an early age.....	-	-	-	x	-

X = Response
- = No Response

Table 9 (Continued)

Dislike the SBC	40%	10%	40%	0%	10%
Reasons for not likings SBC:					
1. Takes to longe to cook meals.....	x	x	x	-	-
2. The food is not properly cooked.....	-	-	-	-	x
3. Can not be used year round or during rainy season.....	x	-	x	-	-
4. Will not eat sun cooked food.....	-	x	-	-	-
5. Solar cooked foods are harmful.....	-	-	-	-	x
6. Enemies can put something harmful in food...	-	x	-	-	-
7. Pot of food can be stolen.....	-	x	-	-	-
8. SBC looks expensive, but wood is free on farm land.....	-	-	x	-	-

X = Response
- = No Response

Table 10: Would Like to Own SBC and Recommend Use to Others

	Makeni	Kabala	Rokupr	Njala Taiama	Njala Labor
Would like to own SBC	80%	90%	80%	100%	90%
Reasons:	1. Preserve forest	1. To spread technology	1. Makes cooking fun and relaxing	1. To spread new tech-	1. Easy to use
	2. Prove that without wood one can cook with SBC	2. Prove it can cook	2. Gives time that can be	2. Its economical	2. Save money spent on wood
	3. Save time, money and energy		3. Smokeless and not messy	3. Would recommend it for pregnant & lactating mothers to give them more rest while cooking	3. Recommend to all single men
	4. Encourages its use		4. Can be carried grounds	4. Its handy to carry to farm	4. If it can be used prepare large quantity of food

CONSTRUCTION OF SOLAR BOX COOKER USING LOCAL MATERIALS AND ITS ECONOMICS

Among other factors, economic considerations rank high in influencing the acceptability of any technology, particularly when it is being introduced and adapted in a different environment. Moreover, the ease of availability of the components of the technology is of equal importance. It was in view of the foregoing that an attempt was made to use local materials in the construction of the solar box cooker.

Construction

One of the main components which was found necessary to be replaced in the original SBC was the card board which made up the main structure of the cooker. This was replaced in one instance by plywood and in another by "poka", a wood like material obtained from the mid-rib of a particular palm tree that grows in swampy areas. In both cases the pieces of cardboard and newspapers used for holding the inner box and for providing insulation were replaced by pieces of plywood and poka respectively.

When tested without food included, temperatures ranging from 250 - 300^{o}F were obtained. This was comparable to that of the original Kerr-Cole Solar Box Cooker. In each of the

cookers various recipes were tried with encouraging results obtained.

Economics

A comparison on the costs of the original Kerr-Cole SBC with those constructed using local materials was made. All were further compared in terms of cost with the fuel wood cooking method.

COSTS OF PRODUCTION OF THREE TYPES OF SOLAR BOX COOKERS

Doing the course of this research project there are three types of SBCs available at the Institute for Agricultural Research:

1. The (imported) cardboard box
2. The plywood box
3. The poka box

Below are the sale prices and costs of the various types of SBCs as of May, 1990 this report.

MARKET PRICE OF THREE SBCs

Type	Cost (Le)	U.S.$*
Cardboard	3,000.00	$ 18.18
Poka	8,850.00	53.63
Plywood	18,920.00	126.13

*The official exchange rate as of May, 1990 was Le $165.00 = $1.00 U.S.

BREAKDOWN OF COSTS OF PRODUCTION OF THE PLYWOOD AND POKA SBCs**

A. Plywood Box

		Le.	U.S. $
Plywood 1/2" 2	-	5,000.00	30.00
Varnish - 1 tin	-	250.00	1.51
Wood preservative - 1 tin	-	500.00	3.13
Nails - 1 packet	-	270.00	1.63
Cascamite glue	-	100.00	.60
Glass (sheet)	-	800.00	4.84
Sand paper	-	400.00	2.42
Evostic		400.00	2.42
Brought forward (B/F)	-	7,720.00	46.78
Board (2 leaves)	-	800.00	4.84
Panel pins	-	200.00	1.21
Aluminum foil	-	1,000.00	6.06
Labour	-	1,500.00	9.09
		Le 11,220.00	68.00

B. Poka Box

		Le.	U.S. $
Poka	-	700.00	4.24
Wood preservative	-	750.00	4.54
Varnish	-	800.00	4.84
Starch	-	150.00	.90
Nails	-	160.00	.96
Sand paper	-	200.00	1.21
Evostick	-	800.00	4.84
1/4" 1/2" plywood	-	1,250.00	7.57
Glass	-	800.00	4.84
Labor	-	800.00	4.84
Aluminum	-	1,000.00	6.06
		Le. 7,410.00	44.90

** The exchange rate was Le $165.00 = $1.00 U.S. However, inflation was continuing it's upward spiral at the time of this writing.

So far, it is apparent form these data that efforts to have had any comparative advantage in the production of these boxes. It is in this light that the consultant engineer is trying out various locally available materials in the production of the boxes.

Of particular interest is that even though the costs of the locally produced boxes far outweigh that of the imported box, the locally produced ones are sturdier; and should therefore last longer if handled properly. Additional analysis is needed to find more economical ways of producing the SBC with local materials.

SURVEY OF FUELWOOD USERS AND PROVIDERS

The most common source of energy for cooking in Sierra Leone is the fuelwood. Apart from the staggering statistic of about 75 percent of the active labor force being farmers and therefore living in rural areas where there is no electricity, more people in the urban areas rely on fuelwood and charcoal as a source of energy for cooking.

There has been tremendous deforestation in several parts of the country. This, therefore, gives rise to developing means of cooking without the use of fuel wood, charcoal, electricity and kerosene as "God's gift' to the energy problem in Sierra Leone.

There is no contention that the initial outlay for a solar box cooker can be staggering, but when one spreads this over the expected life span, (cardboard 5 years, poka

12 years and plywood 20 years) one clearly sees that the technology is very inexpensive. This situation can be appreciated more when one considers the fact that at the present time a bundle of (10kg) wood is sold for Le 50.00 in Freetown and Le40.00 in Bo and other provincial towns and that the average household uses more than two such bundles per day. These prices have more than guardrupled in the last year.

Additionally, prices will continue to rise due to a scarcity of a product that has a constant demand especially in rural areas where there is no substitute for fuelwood. In the western area fuelwood is gradually becoming prohibitive, making the solar box a very welcome and timely idea.

Since the use of conventional sampling techniques would have led to much larger sample sizes than available resources would permit, sample sizes were determined arbitrarily, as a result, seven enumeration areas were identified with a sample of 60 fuelwood users and another of 60 fuelwood providers selected as follows:

Area	No. of Providers	No. of Users
Freetown	9	18
Godrich	10	9
Bonkabapi	3	6
Njala	7	9
Villages around Njala	10	6
Taiama - Bo Highway	12	0
Bo Town	9	12
Total	60	60

The choice of the number of respondents per enumera-

tion area was based on weighted averages.

Generally, there has been a very significant increase in the price of fuelwood over the last year. In most of the study areas, an increase of up to 100 percent has been recorded. In some areas, despite this increase, there has been a reduction in the size of the bundle of wood.

Moreover, contrary to the general belief that most of the fuelwood sold along the highways as bought by fuelwood trucks, observations from the data collection exercise have revealed that most of the fuelwood is now purchased by "Tankers" with the bulk destined for Freetown. It has also been observed that in large cities/towns, fuelwood is usually purchased very close to the residence of the buyer who invariably uses it only for cooking.

It has, however, been difficult to estimate the amount of fuelwood sold in 1988 by the providers questioned. This has been mainly due to the lack of record keeping, and partly to the choice of some respondents who were not in business in 1988. The researchers has tried to solve this problem by finding out, through a series of questions - the average amount of wood sold per week, the peak season for sales, and an estimate of the amount of money made from such sales in 1988.

Another problem was the estimation of daily amounts of fuelwood used; this has emanated from the fact that the

size of the bundles vary greatly in the different enumeration areas. However, this problem was addressed by weighing samples of these bundles in each area wherein an average is obtained which will be used for comparison across areas.

TRAINING AND WORKSHOPS

In preparation for testing the acceptability of the solar box cooker and its products in the rural areas, a one week training course was organized for the Institute's Nutrition Instructors (NI) who are in the various zones. The training took place at the Institute's headquarter at Njala in late February 1989. During this period, NI's were trained on the use and handling of the solar box cookers. More important, they were shown how to prepare a variety of local recipes which had been developed at the Nutrition Laboratory at Njala in anticipation of their use in the rural areas.

After the training, each zone was supplied with one solar box cooker to be used in demonstrations in each zone. In the following months several such demonstrations were held in all the zones.

In early March 1989, the Institute of Agricultural Research had a work program conference during which the SBC was featured prominently. The SBC Project activities formed the main component of the review of the annual activities presented by the Nutrition Department of the Institute.

This conference provided the first channel for the

dissemination of the SBC technology being attended by a cross section of Agricultural Scientists and Civil servants from all parts of the country.

A solar box utilization and dissemination workshop was organized at the Institute of Agricultural Research at Njala from April 9-11, 1990. The main objective of the workshop was to further push the idea of the SBC to a greater audience through appropriate channels. The importance of the potential of the SBC in helping to protect the environment from deforestation by reducing the pressure on fuelwood usage was emphasized.

Its role in cooking and water pasteurization was also stressed. The workshop was attended by forty participants drawn from various ministries and non-governmental organizations including farmers from the surrounding villages.

CONCLUSIONS AND RECOMMENDATION

All the objectives set in the project document were accomplished. In addition to these required objectives other related activities which were found to be necessary were also undertaken. This was mainly in the area of extending and popularizing the solar box cooker and the use of local materials in its construction.

The effectiveness of the SBC in cooking local foods and the eradication of pathogenic micro-organisms in such foods together with pasturizing water was ascertained beyond doubt.

There is an apparent enthusiasm for the SBC in Sierra Leone with high hopes for rapid adoption of the technology. It appears that the adoption rate will be faster in the urban areas than in the rural areas. Primarily because of the persistent increase in the already high price of fuel-wood in the urban areas with no comparable cost effective alternative to the SBC. The SBC will be more attractive to small families and even more to those families where both parents have to go to work which is a common situation in urban areas.

There is a need to extend the project for at least another year so that more research could be done on the use of local materials for the construction of the SBC which could further lead to a reduction in its cost thereby enabling more people to purchase the cooker. It is necessary for a workshop for the construction of the SBC to be organized so that more people will be able to construct their own boxes. This workshop could be used as a forum to further expose the technology to the people.

APPENDIX A

Recipe Development

RECIPE DEVELOPMENT

Initial observations revealed that the SBC would make greater impact in its use for cooking food. It was therefore necessary to identify which of the local dishes could be prepared using the SBC and the necessary modifications that were required in order to obtain better results.

At the initial stage, there was great pessimism with regards to the cooking ability of the SBC particularly traditional foods due to its inherent nature. With the solar box it is required that all the ingredients are mixed together and then placed in the cooker which should remain closed until the food is cooked. Opening of the box allows for the escape of heat which causes a delay in cooking. In the traditional system, ingredients are added in a set sequence at definite intervals with an ocassional stirring of the mixture.

This background gave impetus toward the introduction of the SBC as a cost effective tool for meal preparation and fuel savings. Through exercises undertaken, it was discovered that traditional dishes could be prepared by mixing all the ingredients together for cooking in the SBC Following this, several local dishes were tried with remarkable success. These dishes, prepared experimentally, were accepted with much enthusiam, thus offering hope for the success of this project in Sierra Leone.

The major recipes developed are described below.

Recipe Development

a) Rice

Rice is the staple food of Sierra Leoneans and thus forms the main component of the diet of the people. It was one of the first products tried in the solar box cooker.

Both local (rough) and imported rice were tried. In the first trial, the ratio of water to rice was 2 to 1; in both types it was found that the water used was too much. After 4 hours 20 minutes, the rice was found to be cooked but still contained water. It was however, observed that the volume of rice increased by 100%. Based on this finding, two types of imported rice, long grain and short grain were tried with a reduced ratio of 1 1/2 to 1. After 4 hours 30 minutes, they were both found to be well cooked with no excess water.

When the local par-boiled rice was used, unlike the local rough rice and imported ones, the water to rice ratio of 2 to 1 was found to be adequate. The rice was well cooked after 4 hours 30 minutes and there was no excess water.

b) Millet

This is an another important cereal locally called "fundi" which is mainly consumed in the northern part of Sierra Leone. The volume of water to millet ratio of 1 to 1 was found to be most appropriate. It was well cooked after 2 1/2 hours.

Sauces

Rice is normally eaten with a variety of sauces. The preparation of some of the most popular ones were tried in the solar box cooker. They included:

i. Cassava Leaf Sauce

Cassava leaf sauce which is prepared using the vegetable cassava leaves together with other ingredients is the most popular sauce in Sierra Leone. There is the general belief that for good taste, the pounded leaves must be properly cooked before adding oil and the other ingredients.

Two methods of preparation were used; in one the pounded leaves were first steamed while in the other the raw pounded leaves were used. Each was put in a separate pot and then mixed with the necessary ingredients as indicated in the recipe. The pots were placed in a solar box cooker and the contents were found to be properly cooked after 4 hours 20 minutes.

When tested by various people, they could not distinguish between the two and both were reported to have a good flavor. However, the unsteamed cassava leaf was found to be somewhat darker in color, which is usually preferred. There was also an increase in volume, more than the steamed Cassava leaves. It was also discovered that adding all the ingredients together with pounded leaves made little difference in the final taste of the sauce.

ii. Potato Leaves

Potato leaves sauce is the second most popular sauce in Sierra Leone. Traditionally all other ingredients are first properly cooked before the shreaded potato leaves are added. In actual fact, the time of adding the potato leaves depends on how soft one wants the leaves in the end; for the longer they stay in the pot the softer they become.

In the trial, most of the ingredients were allowed to cook for 3 hours, after which the shreaded potato leaves together with the pepper and onions were added and then left to cook for another hour. Overall, it took 4 hours to cook the sauce. The flavor was excellent and all ingredients were properly cooked with the leaves

crispy as desired by most people.

iii. Groundnut Soup

Groundnut soup appears to be the most adapted to solar cooking among all the local dishes tried. All ingredients together with a greater than usual proportion of groundnut were thoroughly mixed and the final mixture placed in the solar box cooker. After 4 hours 30 minutes, all ingredients were found to be well cooked and the sauce had an excellent flavor.

iv. Beans Stew

This dish is locally called "Abobor" with beans being the main component. The beans were properly cooked for 5 hours the previous day. The boiled beans were then mixed together with the necessary ingredients as indicated in the recipe and then placed in the solar box cooker. After 4 hours 35 minutes the sauce was found to be properly cooked with an excellent flavor.

It was observed that, the beans did not absorb all the water that was added as the sauce was found to be a bit watery. Use of little or no water is therefore recommended. The water already retained by the beans during its initial cooking together with that in the onion and pepper would be just adequate. Moreover, in order to thicken

the sauce, it is advisable to mash some of the beans against the side of the pot and mix thoroughly.

Pemahun

This is a traditional dish in which rice and potato leaves are cooked together in the same pot. The usual practice is to first boil the rice for some time until most of the water has been absorbed by the rice. Shreaded potato leaves are mixed with other ingredients and then spread over the rice in the pot. It is the steam which evolves from the rice that cooks the potato leaves and other ingredients. A similar procedure was followed and the final product was very good which was highly approved by tasters. It took 3 hours and 30 minutes to complete the cooking.

Ebbeh

Ebbeh is prepared by mixing fresh cassava, yams and sweet potatoes together with other ingredients in the same pot. In the end a porridge like product is obtained. In the trial, the various tubers were cut into small chunks to which some water and other ingredients were added and placed in the solar box cooker. The tubers and all other ingredients were found to be properly cooked after 4 hours 30 minutes. The flavor was rated good.

Oleleh

This is a local product made from cowpea paste mixed with a few ingredients as indicated in the recipe. By the

nature of its preparation, it is well suited to solar box cooking.

Traditionally, a pot is about half filled with water and a wire mesh is fitted in the pot just above the water level. The pot is then put on fire. Small bits of the mixture of cowpea paste and other ingredients wrapped in banana leaves are then placed on the iron mesh in the pot. This is to make sure that the oleleh receives heat slowly and gently through the steam.

Inherently, the solar box cooker transfers heat slowly and gently to the products in the pot. In the trial some water was sprinkled in the pot and the oleleh was wrapped in aluminum foil instead of banana leaves as they were unavailable. The wrapped oleleh were then put in the pot which was placed into the solar box cooker. The oleleh which was ready after 2 hours 30 minutes tasted quite well.

Tubers

The tubers, cassava, sweet potatoes, and yams are increasingly becoming important to Sierra Leoneans. They are, particularly cassava, frequently substituted for rice during hunger periods.

In the trial, two methods of preparation were used - boiling and baking. In the former they were each boiled with water as is the usual practice, while in the latter no water was added; it was only the fresh tubers which were placed in the pot.

All boiled and baked tubers were found to be well done after 2 hours. However, when the baked cassava was left to stand for a few hours, it become hard and rubbery due to a loss of moisture. It is recommended that this product be served immediately upon removal from the cooker. Unlike cassava, the baked yam and sweet potatoes retained their moisture and attendant softness even after standing for a few hours. In general, tasters preferred the boiled tubers to those baked.

The following types of cakes were successfully b ked in the solar box cooker.

i. Cassava coconut buns

ii. Rock buns

iii. Potato wheat cakes

iv. Banana bread

v. Cowpea tea cakes

All the products were generally excellent with good color, texture and flavor.

APPENDIX B

SURVEY INSTRUMENTS

- FUELWOOD SURVEY
- TASTE ACCEPTABILITY

SOLAR COOKER PROJECT

SOUTHERN UNIVERSITY/INSTITUTE OF AGRIC. RESEARCH

Economic Analysis of Fuel Wood Usage with and Without the Cole-Kerr Solar Cooker

Survey Instrument for Fuel Wood Providers

1. Enumerator: _____
2. Date: _____
3. Area/Locations: _____
4. Name of Respondent: _____ Sex: _____
5. Unit of Measure of Fuelwood: _____
6. Price Range per Unit for 1988: _____
7. Present Price per Unit: _____
8. Estimated Amount Sold in 1988: _____
9. Type of Buyers a. Fuelwood trucks: _____
   b. Private vehicles: _____
   c. Other (Specify): _____
10. Source of Fuelwood a. Myself: _____
    b. Fuelwood Trucks: _____
    c. Other (Specify): _____
11. Towns Fuel Wood Taken to: _____
    _____
12. Other Information: _____
    _____
    _____
13. Comments: _____
    _____
    _____
    _____

SOLAR COOKER PROJECT

SOUTHERN UNIVERSITY/INSTITUTE OF AGRIC. RESEARCH

Economic analysis of Fuel Wood Usage with and without the Use of the Cole-Kerr Solar Box Cooker

Survey Instrument for Fuel Wood Users

1. Enumerator: _____
2. Date: _____
3. Location: _____
4. Respondent: _____
5. Estimated Daily Amount of Fuel Wood Usage: _____

_____

6. Distance Fuel Wood Transported from Seller _____
7. Estimated Cost of Fuel Wood by Unit _____
8. Methods used to Transporte Fuel Wood to the House _____

_____

9. Type of Store/Cooking Device Used _____
10. Estimated Amount of Time Spent Cooking Meals per day _____

_____

11. List Foods Prepared for the Day _____

_____

12. Other Information _____

_____

_____

13. Comments _____

_____

_____

SOLAR BOX COOKER PROJECT
SOUTHERN UNIVERSITY/USDA/INSTITUTE OF AGRICULTURAL RESEARCH
NJALA UNIVERSITY COLLEGE

TASTE TEST

1. Location (Village/Institute)_____ Date_____

2. Person providing information_____

TRIAL 1:

3. Can you detect a difference in the taste of these samples? Yes___ No___

4. Which is the odd sample? 1_____ 2_____ 3_____

5. Briefly indicate why you think there is a difference. _____

_____

6. Which would you prefer to serve your family and friends? 1_____
2_____ 3_____

7. TRIAL 2:

7. Can you detect a difference in the taste of these samples? Yes___ No___

8. Which is the odd sample? 1_____ 2_____ 3_____

9. Briefly indicate why you think there is a difference. _____

_____

10. Which would you prefer to serve your family and friends? 1_____
2_____ 3_____

TRIAL 3:

11. Can you detect a difference in the taste of these samples? Yes____ No____

12. Which is the odd sample? 1_____ 2_____ 3_____

13. Briefly indicate why you think there is a difference? _____

_____

14. Which would you prefer to serve your family and friends? 1_____
2_____ 3_____.

TRIAL 4: TWO PLATES - ONE TRADITIONAL, ONE SBC.

15. How much do you like or dislike sample A?
Like very much_____ Like_____ Undecided_____
Dislike_____ Dislike very much_____

16. How much do you like or dislike sample B?
Like very much_____ Like_____ Undecided_____
Dislike_____ Dislike very much_____

17. Which would you prefer to serve your family and friends? 1_____
2_____ 3_____

18. Sex of respondent: Male_____ Female:_____

19. Age of respondent:_____

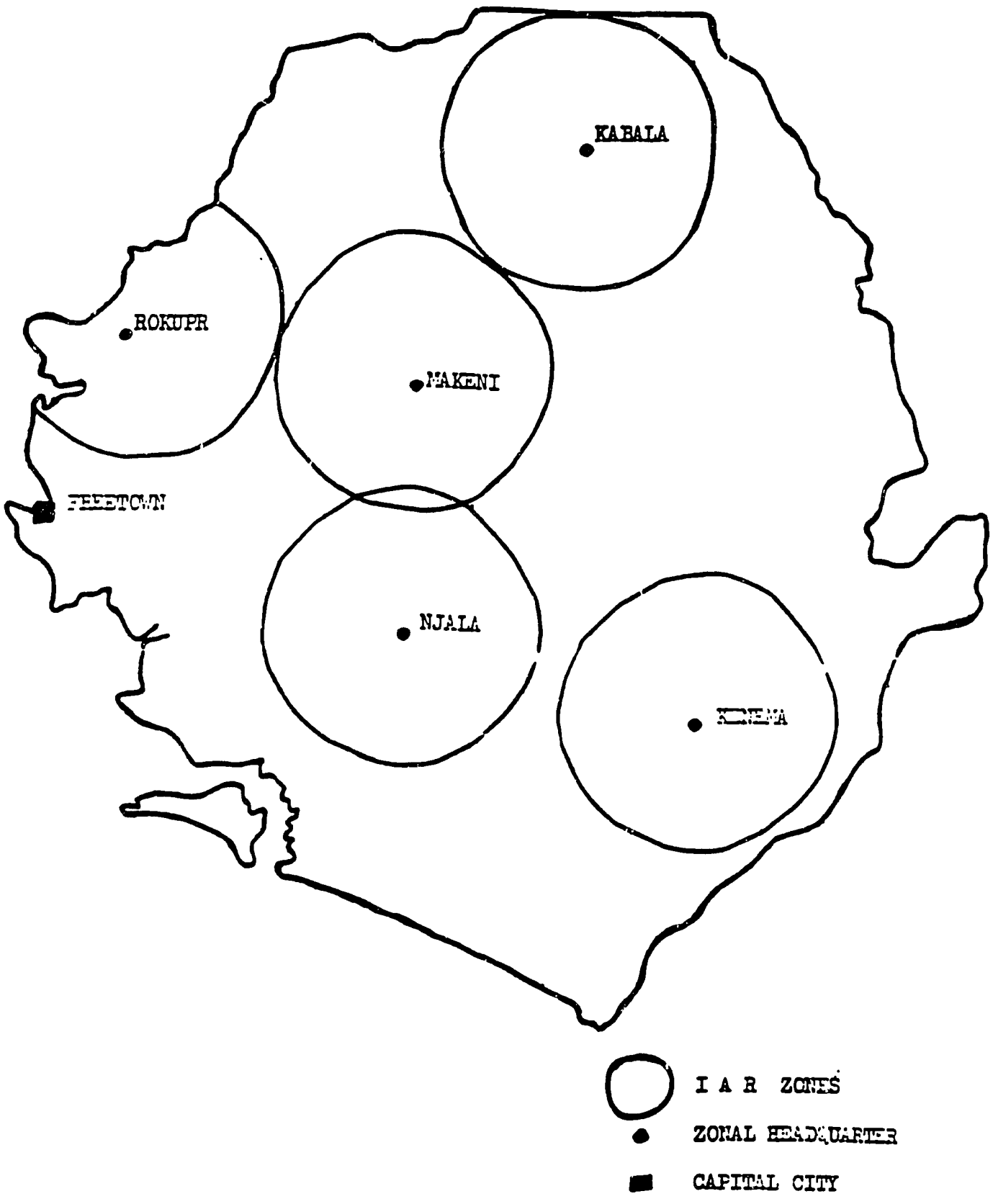
20. Family Size:_____

APPENDIX C

Map of Sierra Leone Showing

IAR Zones

MAP OF SIERRA LEONE SHOWING IAR ZONES



APPENDIX D

Presentations

Prospective Technical Papers

Presentations at Conferences and Seminars

"Introduction of the Solar Box Cooker in Sierra Leone" - Solar Cooker International Advisory Board Sacramento, California - Oct. 27-28, 1990 - Barbara Carpenter.

"International Development - The Solar Box Cooker" - Southern University/Louisiana State University Association of Women In Development May, 1990 - Barbara Carpenter.

"Introduction of the Solar Box Cooker in Sierra Leone, West Africa and Fuelwood Depletion", Seminar presented in the College of Agriculture and Home Economics, Southern University, October, 1989 - Leroy Davis.

"Technology transfer of the Solar Box Cooker to village environment in Sierra Leone", a W. K. Kellog Foundtion Fellows' Symposium, Battle Creek, Michigan, December, 1989 - Leroy Davis.

"Analysis of the International Involvement of 1980 universities: The case of the Solar Box Cooker", a presentation a the Annual meeting the Association of Social and Behavioral Sciences, Tallahassee Florida, March, 1990 - Leroy Davis and John Moland.

Prospective Technical Papers

1. "Fuelwood depletion in Sierra Leone: Potential for Solar Box Technology", to be published in appropriate journals/or other media.

2. "Health, nutrition, acceptability and economic potential of the Solar Box Cooker in Sierra Leone", a complete technical study of the technology transfer of the SBC,- - all researchers involved.