FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS.

FIRST PROGRESS REPORT ON THE PROJECT TCP/GHA/4452 (C), ENTITLED "INTEGRATED GRADING AND SOLAR DRYING OF MEAT".

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ABSTRACT.

A modified cabinet solar dryer based on an existing and functional cabinet solar dryer was constructed on a concrete floor collector and tested for its drying efficiency with 20mm. thick lean beef strips.

The exceptionally faster drying rate of the 20mm. thick meat strips obtained in this experiment as compared with previous similar drying experiments using cabinet solar dryers, suggest a marked improvement in the modified cabinet solar dryer constructed. This improvement was however complemented by the conducive weather conditions that prevailed during the drying period as indicated by weather data monitored.

The solar dried meat product obtained in this experiment was exceptionally shelf stable and wholesome for human consumption based on chemical, microbiological and water activity analysis carried out on the dried meat samples.

Sensory aspects of the dried meat product was however poor, in respect of meat texture and acceptability. This was probably due to the leanness and dryness of the meat strips coupled with the unfamiliarity of the meat product as a normal food item in the diet of the taste panellists.

1. INTRODUCTION.

Following a preliminary familiarization visit to the project site from 4 to 11 November, 1994 by the International and National Consultants for the project, a report on the visit was submitted to the FAO Headquarters for Africa, Accra, by the National Consultant.

The contents of the report highlighted discussions on the project document and the consensus reached by the project team members with respect to the execution of the project. (Please refer to the Preliminary report on visit to the project site at the UST, Kumasi, submitted to the FAO Headquarters for Africa, Accra, November,1994).

Among the key discussions on the project document terms of references was the review of the locally constructed solar dryers and the recommendations necessary for improvement regarding construction techniques and materials.

This section of the terms of references was discussed in detail by the International and National Consultants.

Among the two locally designed solar dryer designs submitted for discussions, one of them, a cabinet solar dryer, was selected for the modifications and improvement to be constructed (Please refer to Appendix I for the design details of the cabinet solar dryer selected for modification).

The important modifications and improvements to be made on the existing cabinet solar dryer were as follows :

- Improvement in collector length to between 4 to 5 metres from the existing 1.56 metres collector length.
- A maximum collector height of 10 metres to be made.

NB: This modification cannot be fixed in natural convection solar dryer systems because the collector height depends upon the improvement in air flow required within the drying chamber. Thus, a larger inlet air duct area facilitating improved air flow in a natural convection solar dryer system will have a higher collector height, while a smaller inlet air duct area, associated with a shorter collector height will not facilitate improved air flow in a natural convection system having an already inherently poor internal air flow.

- Separation of the collector and drying chamber into two separate units. This modification was already existing.
- Walls of the drying chamber to be made of concrete materials. On this modification, it was agreed that two types of the modified cabinet solar dryer will be constructed as follows : one with a minimized polyethylene surface comprising of a completely insulated drying chamber made of plywood and lined internally with metal sheeting, and the other similarly constructed but with the drying chamber completely covered with plain polyethylene. The collector size was however to remain unchanged.
- Construction of the cabinet solar dryers on concrete floor with improved insulation on the concrete sides.
- The two modified cabinet solar dryers were to be constructed solely out of local materials and tested as an

alternative against a purely imported, modular tunnel solar dryer incorporating photo voltaic driven fans (Please refer to Appendix II for the design details of the modified cabinet solar dryer constructed).

As a follow up to the preliminary report on the above discussions, a meeting was held on the 20th of November, 1994, at the FAO Regional Office for Africa , Accra, between the FAO Regional Animal Production and Health Officer for Africa, the Assistant FAO Representative for Ghana, the Assistant Project Manager for the project and the National Consultant.

The meeting approved travel by the National Consultant to the project site for fourteen (14) days between 7/01/95 to 21/01/95, to construct one unit of the two modified cabinet solar dryers as described above. (Please refer to Appendix III for the itinerary of activities carried out during the mission with dates).

The National Consultant was also required to carry out drying trials with meat in the constructed solar dryer, monitor weather data during drying and carry out chemical, microbiological and sensory analysis on the dried meat end product.

The International Consultant was required to evaluate preliminary work carried out by the National Consultant on his next mission to the project site.

2. MATERIALS AND METHODS

All materials required for the construction of the modified cabinet solar dryer were obtained and purchased locally (Please refer to Table Ia and Ib below for the material quantities and cost of cabinet solar dryer constructed and dryer physical dimensions).

The solar dryer was constructed using between two to three workers per day. The total man hours used for the completion of the solar dryer was 59 hours.

Meat preparation, solar drying of meat and weather data monitoring during meat drying was carried out after solar dryer construction.

2.1. Meat preparation, drying and weather data monitoring during meat drying.

2.1.1. Meat preparation

Freshly prepared hind quarter beef weighing 31.5 kg., at a cost of ₵0,500.00 Cedis was purchased for the experiment. Trimmed, boneless muscle weighing 6.5 kg. from the hind quarter was used for the experiment. This meat was cut into 20mm thick meat strips. The strips were then incised along the muscle length with a new razor blade at two or three positions . This was done to help open up the muscle to facilitate meat drying. The average length of the meat

Table Ia.

ESTIMATED MATERIAL QUANTITIES AND COST OF SOLAR DRYER CONSTRUCTED.

Item	Quantity	Unit cost (cedis)	Total cost (cedis)
WOOD.			
1. 2"*4"*16'	4	2300.00	9200.00
2. 2"*2"*16'	14	1500.00	21000.00
3. Plywood	4	18000.00	72000.00
4. Cealing battons	1.5 bdls.	4500.0/bd of10	6750.00
OTHER MATERIALS.			
5. Mosquito netting	13.5'	351.00/foot	4725.00
6. Cement	14bags	5500.00	77000.00
7. Plain polyethylene			
a. (main body)	11double metre	750.00/double metre	8254.40
b. for covering plywood surrounding solar dryer	11double metre	750.00/double metre	8254.00
8. Solignum	3/4gal.	3000.00/gal.	2100.00
9. Black paint	1gal.	11600.00	11600.00
10. Thinner	1gal.	6500.00	6500.00
11. Welded mesh	1.5ps.	16500.00/ps	24750.00
12. Kapok	3.3bags	8000.00/bag	26400.00
13. Sand	0.25 of trip used	14000.00/trip	3500.00
14. Stones	one trip used	35000.00/trip	35000.00
15. Glue	3/4 tin used	3500.0/tin	2625.00
16. Kerosene	one beer bottle (625ml)	300.00/bottle	300.00
17. Nails (total used)	2.5lbs.each of 1",1.5",2",2.5",3"	----------	6750.00
18. Total labour (59man hours)	46500.00+30000.00 (artisans+labourers)	---------	76500.00
		GRAND TOTAL COSTS:	403208.00

NB: Cost of 31.5kg H1/4 beef used for meat drying trials was 70500.0 cedis.

Table Ib.

PHYSICAL DIMENSIONS OF SOLAR DRYER CONSTRUCTED.

PARAMETER	DESCRIPTION
1. Dryer type:	Cabinet solar built on concrete floor with base and sides of concrete floor insulated with kapok.
2. Constructing organisation:	Food Research Institute, Accra.
3. Height of drying chamber from ground level:	182cm.
4. Height of drying chamber from dryer floor:	146cm.
5. Volume of drying chamber:	1.87m*m*m.
6. Drying chamber length * breadth:	120cm.* 120cm.
7. Collector length:	400cm.
8. Collector surface area:	4.6m*m.
9. Collector inlet air duct breadth * height:	115cm.* 15cm.
10. Exhaust air duct breadth * height:	112cm.* 15cm.

strips was between 10 to 15cm.

1.5kg. out of the 6.5kg. meat strips cut was blanched for 10 minutes in 90 degrees C hot water containing 2% salt. After draining hot water the blanched meat was coated with a mixture of hot chilli and nutmeg spice at 0.5% of the meat weight. This meat sample was used for the drying weight loss data experiment.

The remaining 4.5kg. meat strips were also blanched in 90 degrees C hot water containing 2% salt for 10 minutes. After draining hot water, the meat strips were strung on a twine and hanged vertically in the dryer for drying. No spice or weight loss data was however collected on this sample.

2.1.2. Weather data monitoring

The following weather parameters were monitored during the drying period: temperature, relative humidity and wind speed.

Temperature was monitored at three different positions, ie. ambient air temperature, temperature of air entering drying chamber from collector and mid- point of drying chamber temperature.

Relative humidity of the ambient air was monitored during the drying period. The relative humidity within the drying chamber could not be monitored because there was only one relative humidity probe in use.

Temperature and relative humidity were monitored between

10.00am to 4.00pm daily for the convenience of the experiment and for the security of the equipment used.

2.1.3. Monitoring of the average rate of weight loss during meat drying

Meat strips for drying weight loss experiment (1.5kg. weight) was divided into six lots, each lot skewed onto a copper rod supported horizontally on the wooden braces in the drying chamber. Each rod with meat strips was labelled and weighed three times daily from the start of the drying to the end of the drying period. Each rod with meat strips at the beginning of the experiment weighed between 225 to 300g. Two drying cycles, ie, two drying days were required to dry the meat strips to almost constant weight .

2.2. Chemical, microbiological, water activity and sensory evaluation carried out on solar dried meat product.

The above analysis were carried out at the Food Research Institute , Accra. For chemical analysis the following were carried out: moisture, fat, protein, ash and salt (%), according to AOAC, 1990 procedures.

For microbiological analysis, total bacterial counts on Plate Count Agar at 30 degrees C for 48 hours and mould and yeast counts on Malt Agar at 30 degrees C for 48 hours were carried out. Water activity was measured using the HI 8564

Thermohygrometer.

Sensory evaluation on dried meat samples was carried out using 22 panellists, to sample dried meat prepared into a palatable traditional light soup under the following quality attributes: colour, tenderness, flavour, juiciness, off-flavour and overall acceptability.

3. RESULTS AND DISCUSSIONS.

3.1. Results of average weather data monitored during drying.

3.1.1. Temperature

Figure I below shows the average ambient air temperature monitored during the drying period. The average maximum ambient temperature attained during the drying period was 37 degrees C and the average minimum 22 degrees C.

Figure II below shows the average inlet air temperature entering the drying chamber from the collector.

Comparing Figures I and II, it can be shown that there was an increase in the ambient air temperature within the collector from 37 degrees C. to 42.5 degrees C. giving a temperature elevation of 5.5 degrees C. within the collector.

In Figure III, there was a further increase in air temperature within the mid- point of the drying chamber above that of the collector air temperature from 42.5 degrees C. to 47 degrees C. giving a temperature elevation of 4.5 degrees C. There was therefore a total temperature elevation 10 degrees C. in ambient air temperature as it flowed through the collector into the drying chamber.

The overall temperature elevation over that of ambient in the solar drying chamber was not very high. This was expected

Temperature Measurements taken during drying of meat strips

Fig. 1

Ambient air temperature versus time

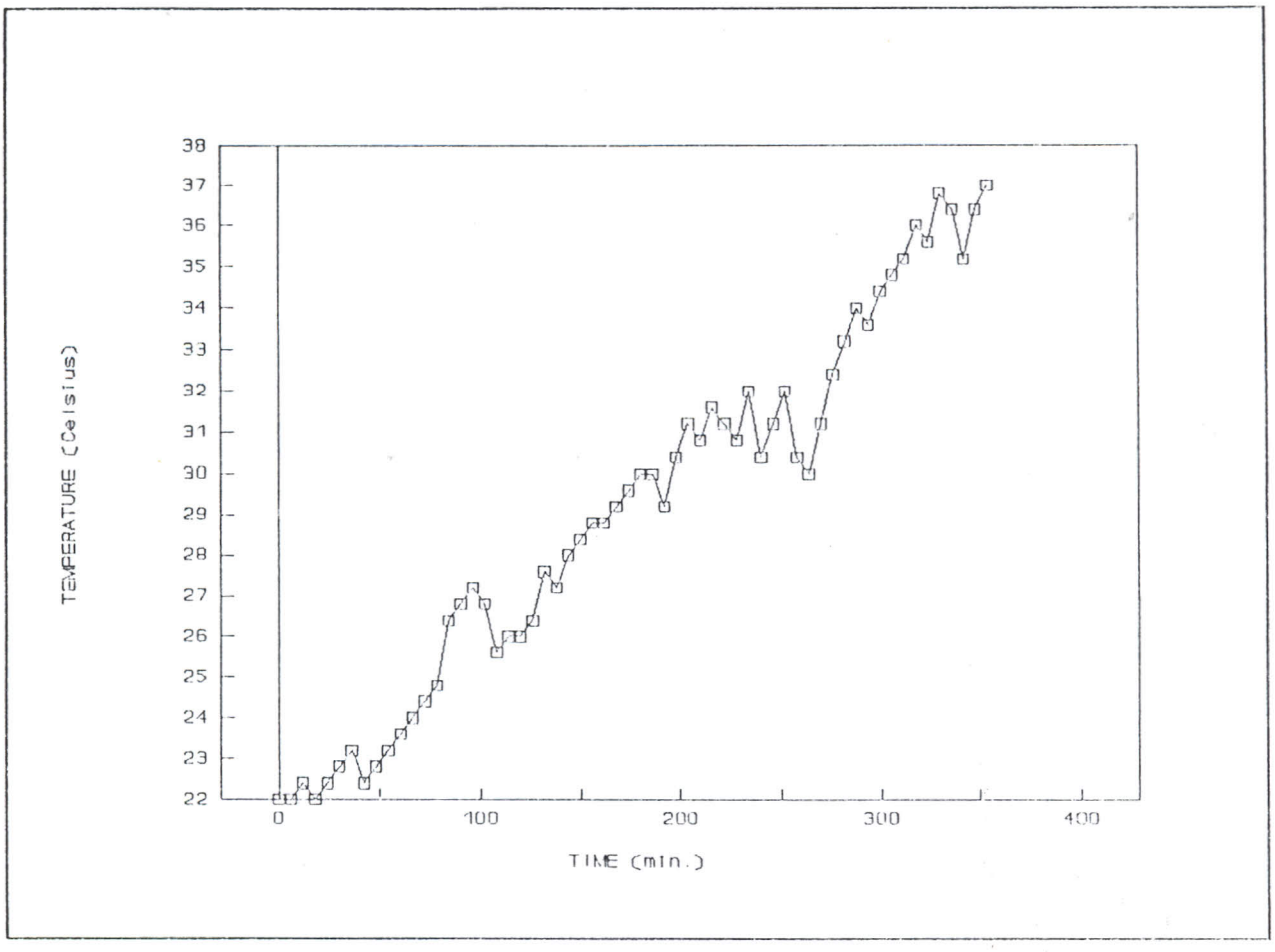


Fig. 2

Inlet air temperature entering drying chamber from collector versus time

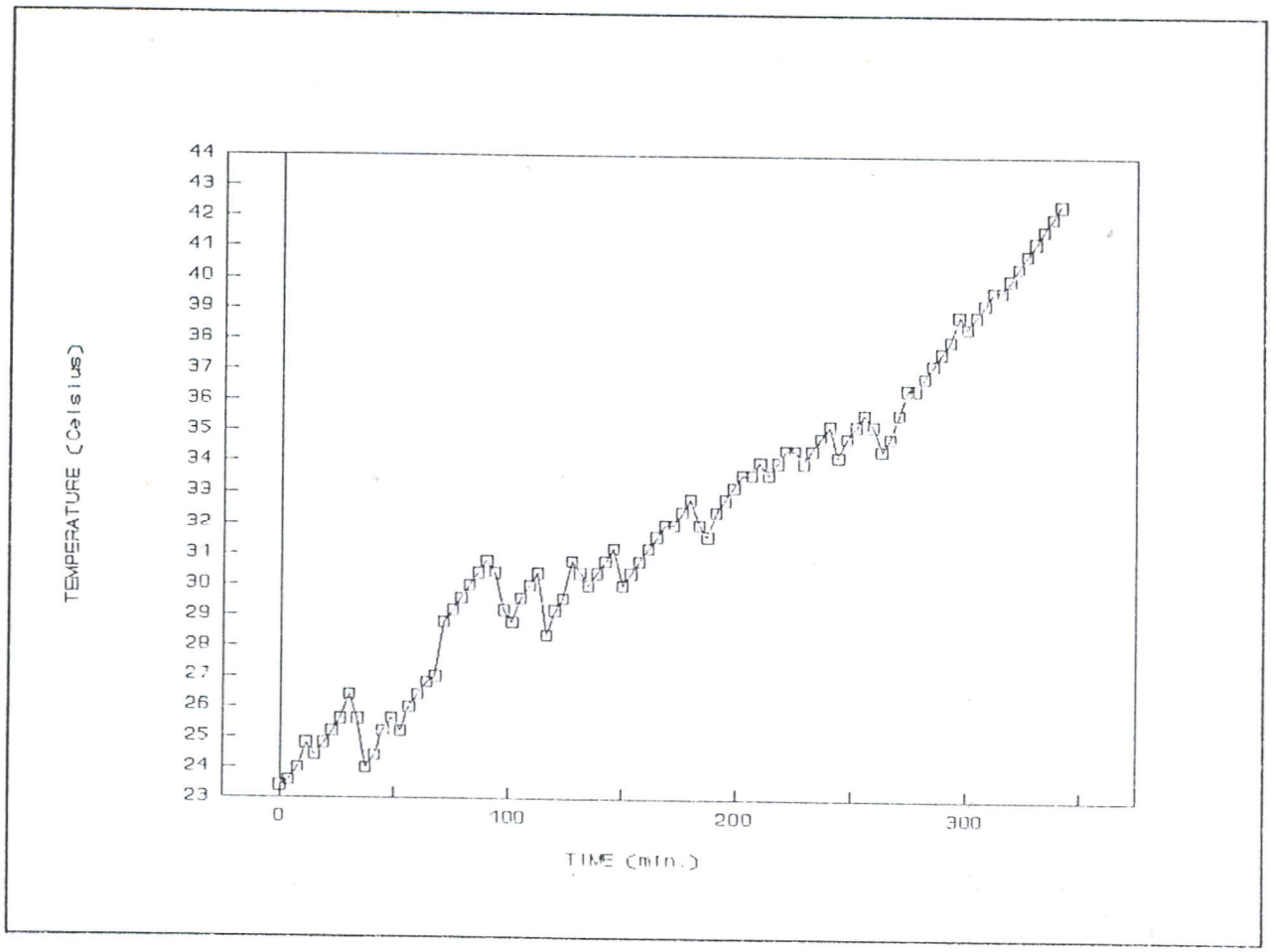
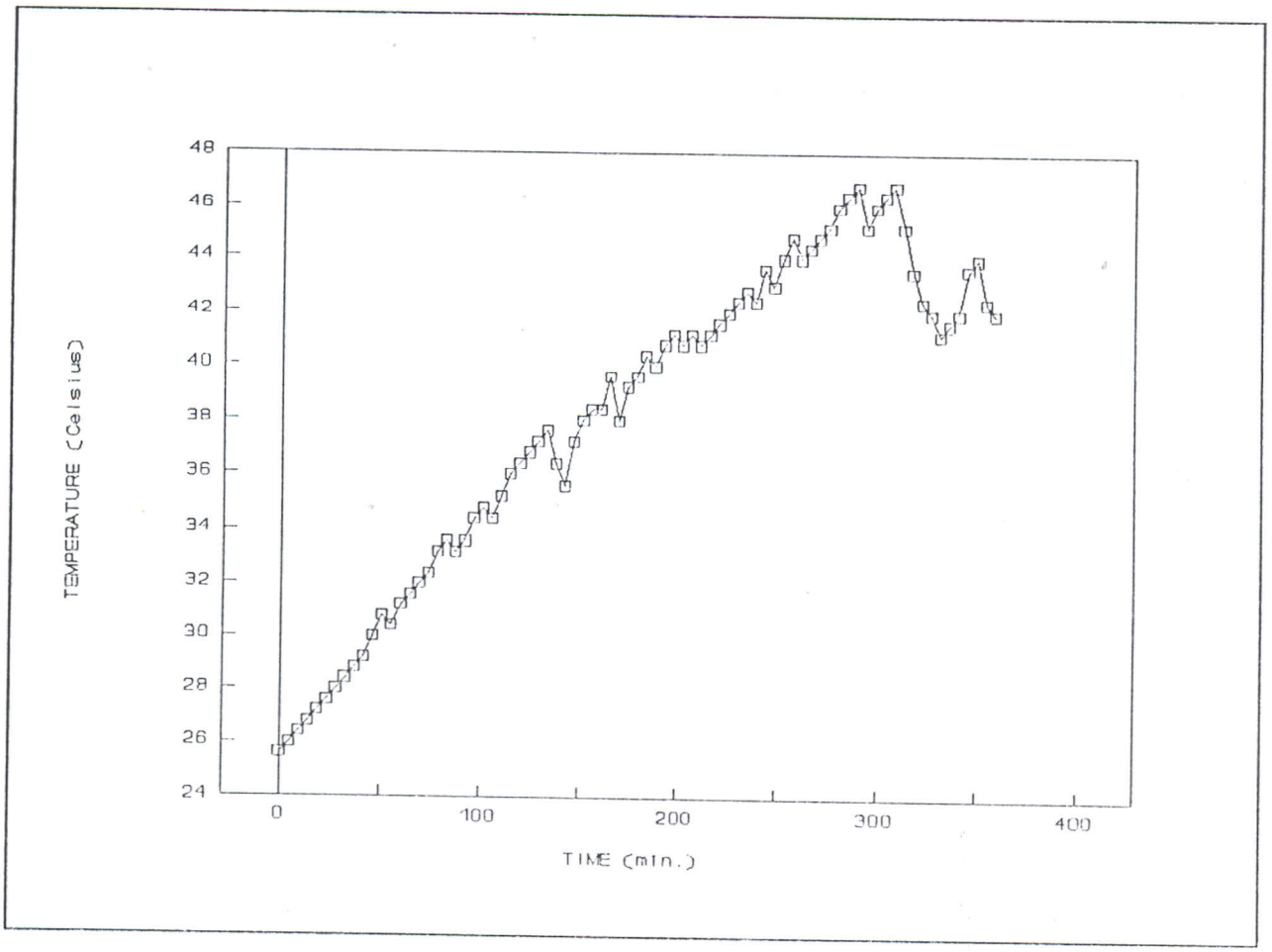


Fig. 3

Mid-point of drying chamber temperature versus time



especially during the dry Harmattan season due to intense fine particles of Harmattan dust which tend to disperse solar radiation during the day. This is supported by the lower average daily solar radiation figure of 15.09 MJ/m*m. for the month of January in Kumasi (Please refer to Section 3.1.4.). The normal daily average solar radiation figure on good sunny days ranges between 16 to 18MJ/m*m. (Personal communication, Meteorological Department, Accra).

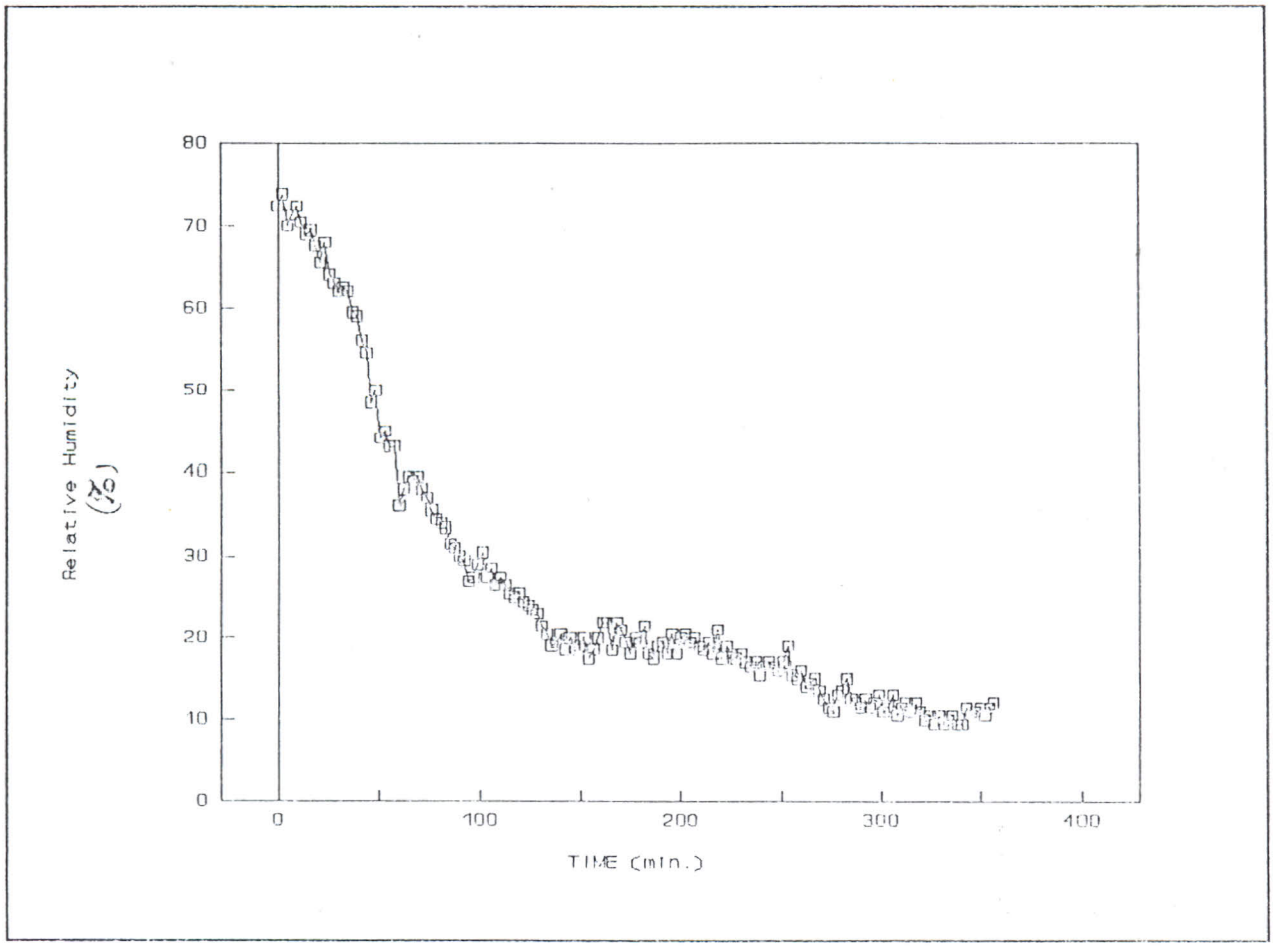
3.1.2. Relative humidity

In Figure IV, the average ambient relative humidity recorded over the drying period showed a significant decrease from 75% in the morning to 11% towards the evening. The low ambient relative humidity attained is attributed to the season of the year and the location of the experiment. The experiment was carried out in January and in Kumasi in the middle zone of the country.

The peak of the Harmattan dry season in Ghana falls between December and January, sometimes extending into February, and the intensity of dryness increases as one goes from the coastal zone to the middle zone and then the northern zone.

Fig. 4

Ambient relative humidity versus time



3.1.3. Air flow rate

The average air flow direction during the drying period was between north-south and south-north.

The average air flow rate monitored within the drying chamber was between 0.8 and 0.9m/s. This was a significant improvement in air flow over previous work done at the Food Research Institute (Tettey, 1994), using a cabinet dryer. The air flow rate obtained in that experiment was 0.24m/s.

The improved air flow in this experiment can be attributed to the larger air duct area which allowed more air to flow into the drying chamber.

3.1.4. Solar radiation

Due to lack of equipment for monitoring the above parameter at the time of carrying out thfs experiment, the average solar radiation data for Kumasi in January was obtained from the Meteorological Department. The average daily value for Kumasi in January was given as 15.09MJ/m*m.

3.2. Results on average rate of weight loss of meat strips during drying.

Figure V below shows the graph of percent original weight of meat strips against time of drying.

The graph shows a drastic loss of weight in meat strips. In the first two hours of drying for example, 18% of the original weight of meat strips was lost, and just after four hours of drying 40% .

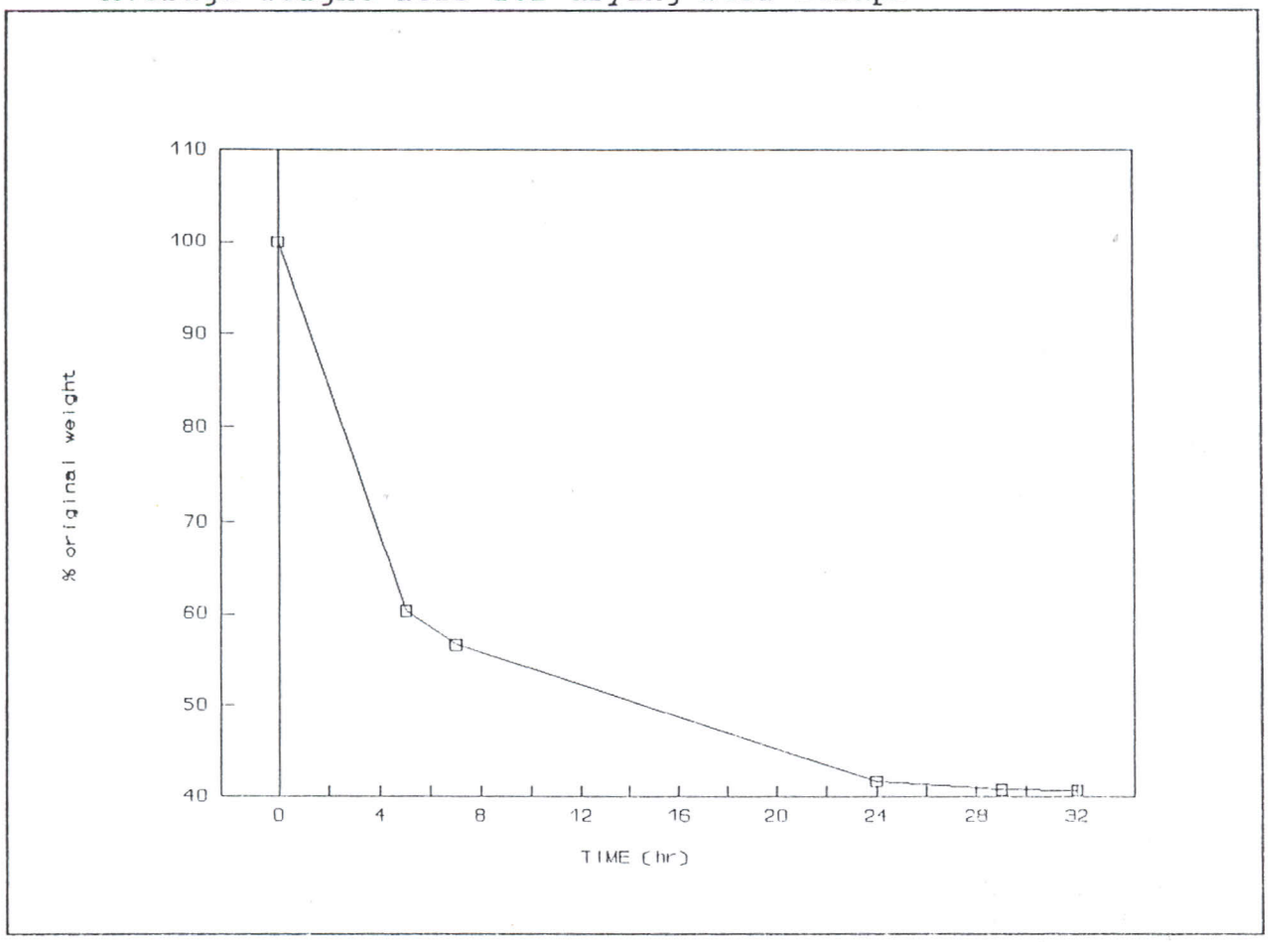
There was a further loss in the weight of meat strips over the first 24 hours of drying amounting to 58% of its original weight. The drying meat samples seemed to have reached their equilibrium drying weight after 24 hours of drying. The final drying period was however over two days (two drying cycles). In previous drying experiments in Accra, in January (Tetteh, et. al. 1993), using similar cabinet solar dryers, 20mm. meat strips dried to relatively stable moisture content over three drying cycles. The meat strips were not however incised as occured in this experiment.

The enhanced drying rate of 20mm. meat strips in this experiment indicated conducive drying conditions within the solar dryer even under relatively lower temperature elevation.

It will be recalled that relative humidity recorded during the drying period reduced during the day to about 15% (less

Fig. 5

Average weight loss for drying beef strips



refer to Section 3.1.2.).

From experience in solar drying, it can be shown that in drying, the condition of the air ie. its relative humidity, speed and the capacity of the air to carry moisture away from drying material accounts more to the drying effect on the material than temperature alone per ce.

The solar dryer used in this experiment requires further testing during a non Harmattan period to obtain more data on the effect of relative humidity, temperature elevation and air flow rate within the drying chamber on the overall efficiency of the dryer in drying meat strips.

3.3. Results of microbiological, chemical, sensory and water activity analysis carried out on solar dried meat strips.

3.3.1. Results of microbiological analysis.

Table II below shows results of microbiological analysis carried out on solar dried meat strips.

Total bacterial counts of up to 10^5 and mould and yeast counts of 10^2 obtained indicated efficient drying of the raw meat material and shelf stability for the dried meat end product. Previous drying trials carried out in Accra using similar cabinet solar dryers with 20mm. meat strips, gave total bacterial counts ranging between 10^7 to 10^9, indicating poor and inefficient drying of the raw meat strips.

Beyond total viable counts of 10^7, the dried meat product may be considered a suspect and unwholesome for human consumption (Thatcher and Clark, 1975).

The safety that may be associated with the consumption of dried meat products with viable counts beyond 10^7, may be due to the prolonged cooking applied to the meat before consumption.

Table II: Results of microbiological analysis carried out on dried meat samples.

SAMPLE	ANALYSIS	COUNTS
Solar dried meat strips.	Total bacterial counts	$1.47 * 10^5$
- do-	Mould and yeast counts	$1.1 * 10^2$
- do-	Culture	Micro-cocci and Bacillus spp.

3.3.2. Results of chemical analysis and water activity analysis.

Table III below shows results of chemical and water activity analysis carried out on dried meat samples.

The moisture content of 17.4% and water activity of 0.62 of the dried meat indicate that the dried meat sample falls within the intermediate moisture range, as it were, conferring shelf stability to the product under ambient storage with suitable packaging of the product.

Table III: Results of chemical and water activity analysis

SAMPLE	ANALYSIS	VALUE (%)
Solar dried meat strips	Moisture	17.4
-do-	Fat	2.9
-do-	Protein	67.9
- do-	Ash	9.3
- do-	Salt	2.9
- do-	Water activity	0.62

The low fat content of the dried meat product ensured that lipid oxidation reactions which can be accelerated under dehydrated conditions of the meat is minimized or prolonged. Lean meat strips were used for drying in this experiment.

The increase in protein content was related to the reduction in moisture content of the dried meat.

The high ash content was related to its value calculated based on 100g of the dried sample.

The increase in salt value was related to the 2% salt infused with the raw meat strips and the reduction in moisture content of the meat product.

3.3.3. Results of sensory analysis

Table IV below shows results on sensory evaluation on dried meat strips.

The important eating quality characteristics indicated by panellists in this analysis point to the following conclusions:

- The dried meat product had poor textural characteristics, being dry and stringy. This was expected because the tenderness of meat is related to factors such as fat and moisture content in the meat apart from others such as sex, maturity of the animal and the post- mortem characteristics of the meat.

The meat strips used in this experiment were trimmed completely of any visible fat. This is supported by the low fat content of the dried meat product (Please refer to Section 3.3.2.).

The effect of drying on the meat muscle structure may also have implications on meat texture. Thus, the fresh meat counterpart will be more tender than its dried form. Similarly, meat flavour may also be adversely affected by drying when compared with the fresh meat flavour. The slight off-flavour indicated by panellists in this experiment was not related to off-odour or spoilage.

Dried meat is quite a new product or food item in Ghana.

This may account for the lower acceptability score by panellists.

It will take sometime to build up consumer acceptability for dried meat products in Ghana.

Table IV: Results of sensory analysis

QUALITY ATTRIBUTE	MEAN SCORE	INFERENCES
Colour	3.9	moderately desirable
Tenderness	3.9	slightly tender
Flavour	2.95	natural beef flavour
Juiciness	1.95	slightly dry
Off-flavour	4.22	slight off-flavour
Overall acceptability	3.09	fair

4. CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER WORK

4.1. Conclusions

The following conclusions are deduced based on the results of the present experiment:

- 20mm. incised meat strips dried at a much faster rate than has ever been achieved with cabinet solar dryer work so far carried out in Ghana.
- Microbiological, chemical and water activity analysis on dried meat strips suggested that the dried meat product was shelf stable and wholesome, when however, suitably packaged to prevent recontamination and rehumidification.
- Sensory analysis indicated poor textural characteristics and lower acceptability.

4.2. Recommendations for further work

The following recommendations are proposed for further work:

- The cabinet solar dryer used in this experiment is a new design and therefore requires further testing.

The concrete floor collector of the dryer also acts as a heat storage bed to store solar energy during the day, to be released in the evening and at night when the temperature falls . Further work is required to determine the heat storage capacity of the storage bed and its effect on the total drying efficiency of the solar dryer.

- The efficient drying of 20mm. thick meat strips in this experiment, suggests further drying trials on the dryer at a different season (having different weather conditions), to ascertain the effect of the solar dryer and weather parameters on the drying efficiency of meat strips.

It is also suggested that thicker meat strips ie. 30mm. thick and incised, be tried for drying.

- To improve the acceptability and consumer demand for the dried meat product, it is suggested that extension work be carried out using questionnaires on identified end users. This will also help to evaluate the economic feasibility of the dried meat product in Ghana.

5.0 REFERENCES

AOAC (1990): Association of Official Analytical Chemists, 5th. Ed. Vol. II.

Tatcher F. S. and Clark, D. S. (1975): ICMSF: International Committee on the Microbiological Safety of Foods. Micro-organisms in Foods (I). University of Toronto Press.

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Tettey, E. C-T. (1994a): Testing of improved cabinet solar dryer for snail meat drying in the hot humid tropics of Ghana. Report submitted to FAO for publication in the FAO African Network on Traditional Meat Preservation Technologies Newsletter.

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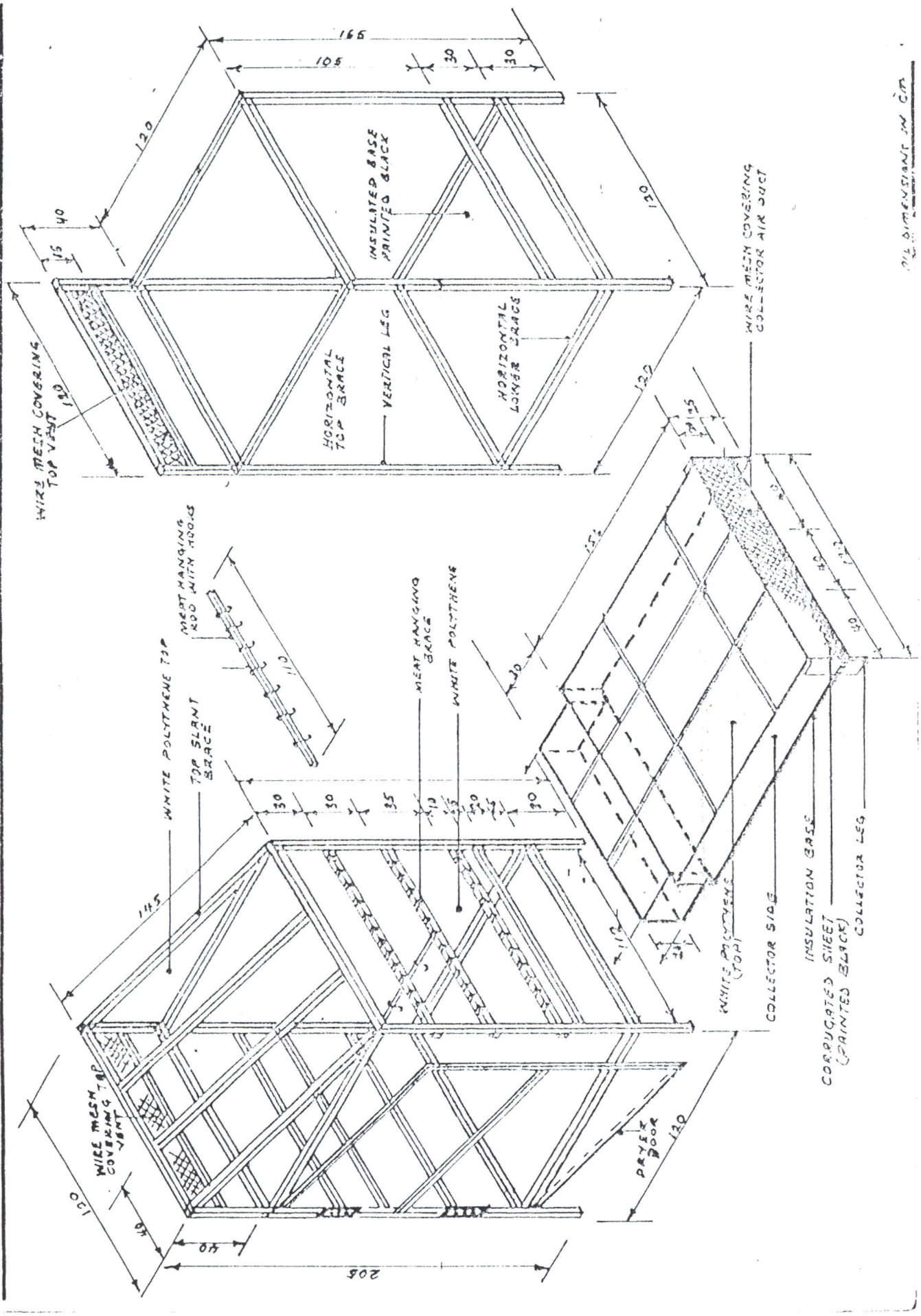
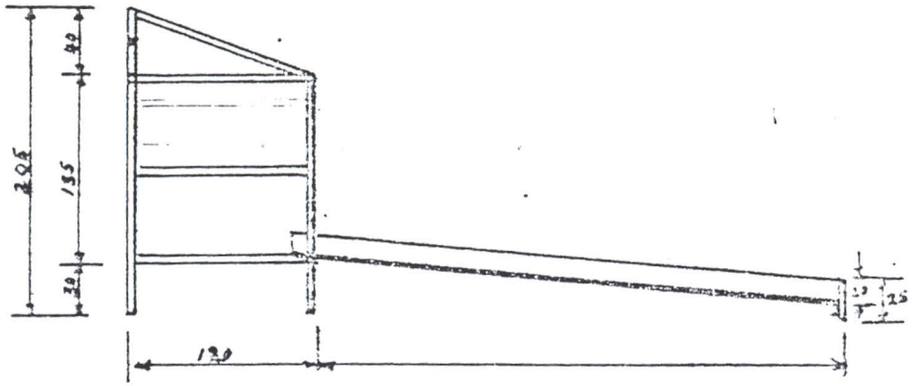
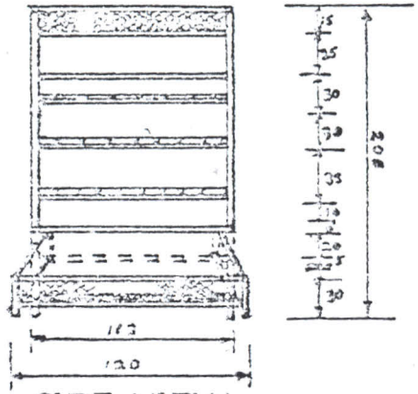
DESIGN DETAILS OF A NATURAL CONVENTION CABINET TYPE SOLAR DRYER IMPROVED



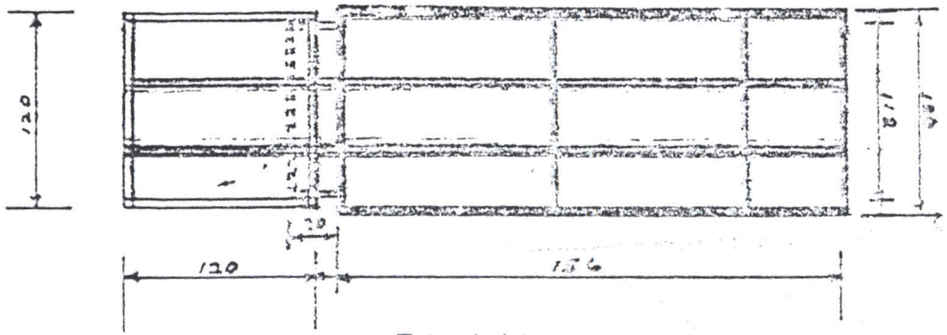
ORTHOGRAPHIC VIEW & DESIGN DETAILS OF A NATURAL CONVENTION CABINET TYPE SOLAR DRYER IMPROVED VERSION



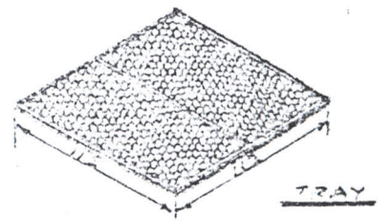
FRONT VIEW



SIDE VIEW



PLAN

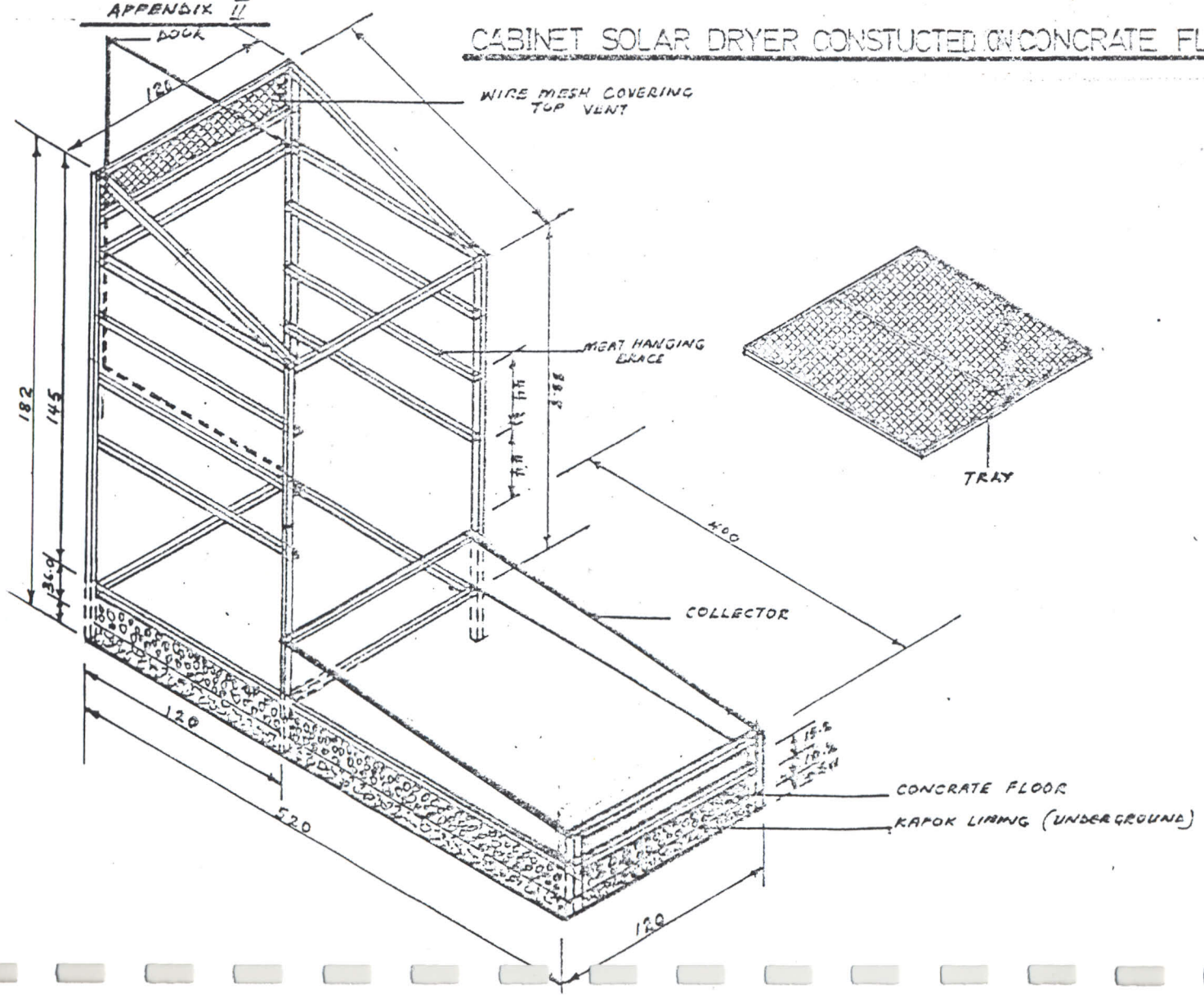


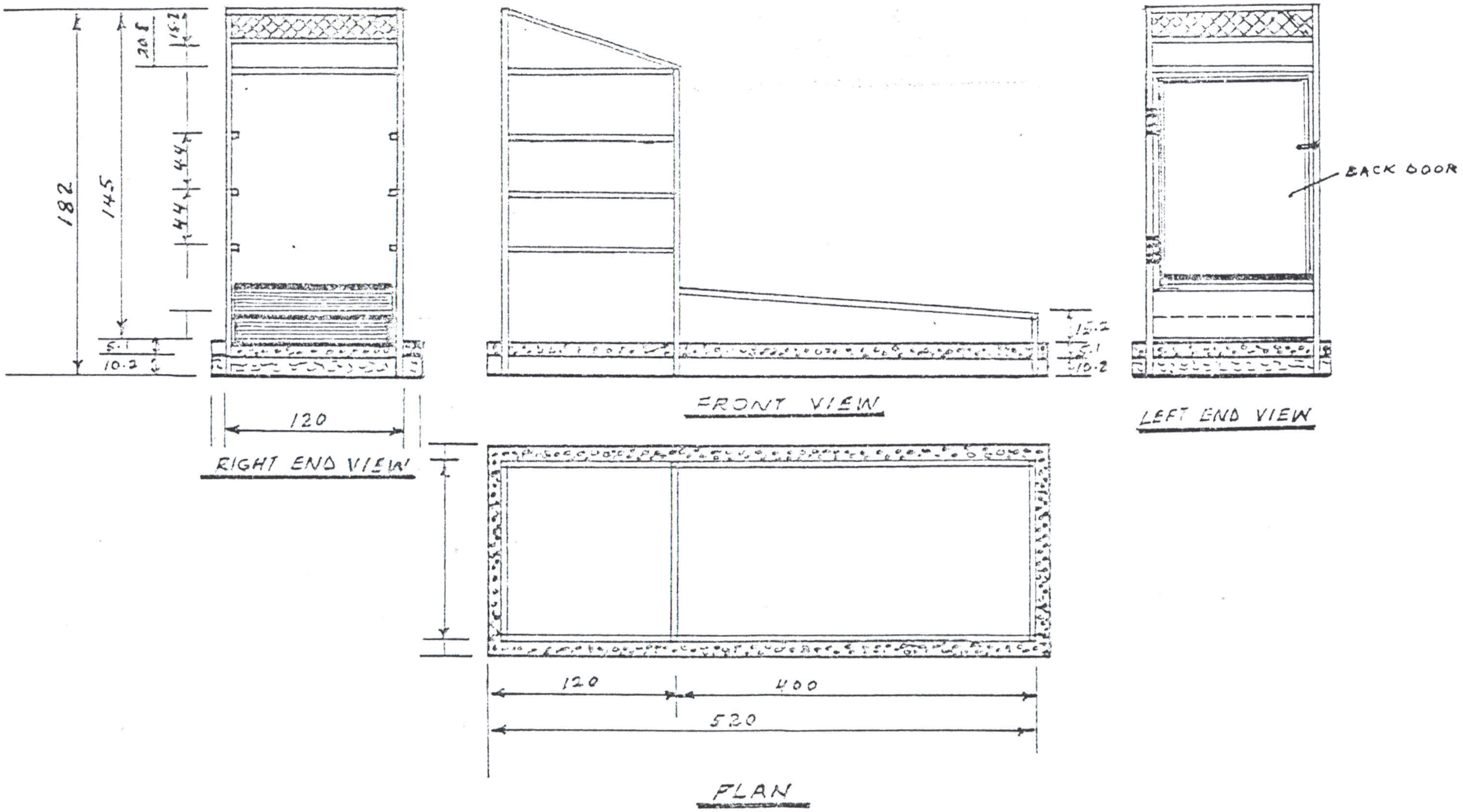
TRAY

ALL DIMENSIONS IN CM

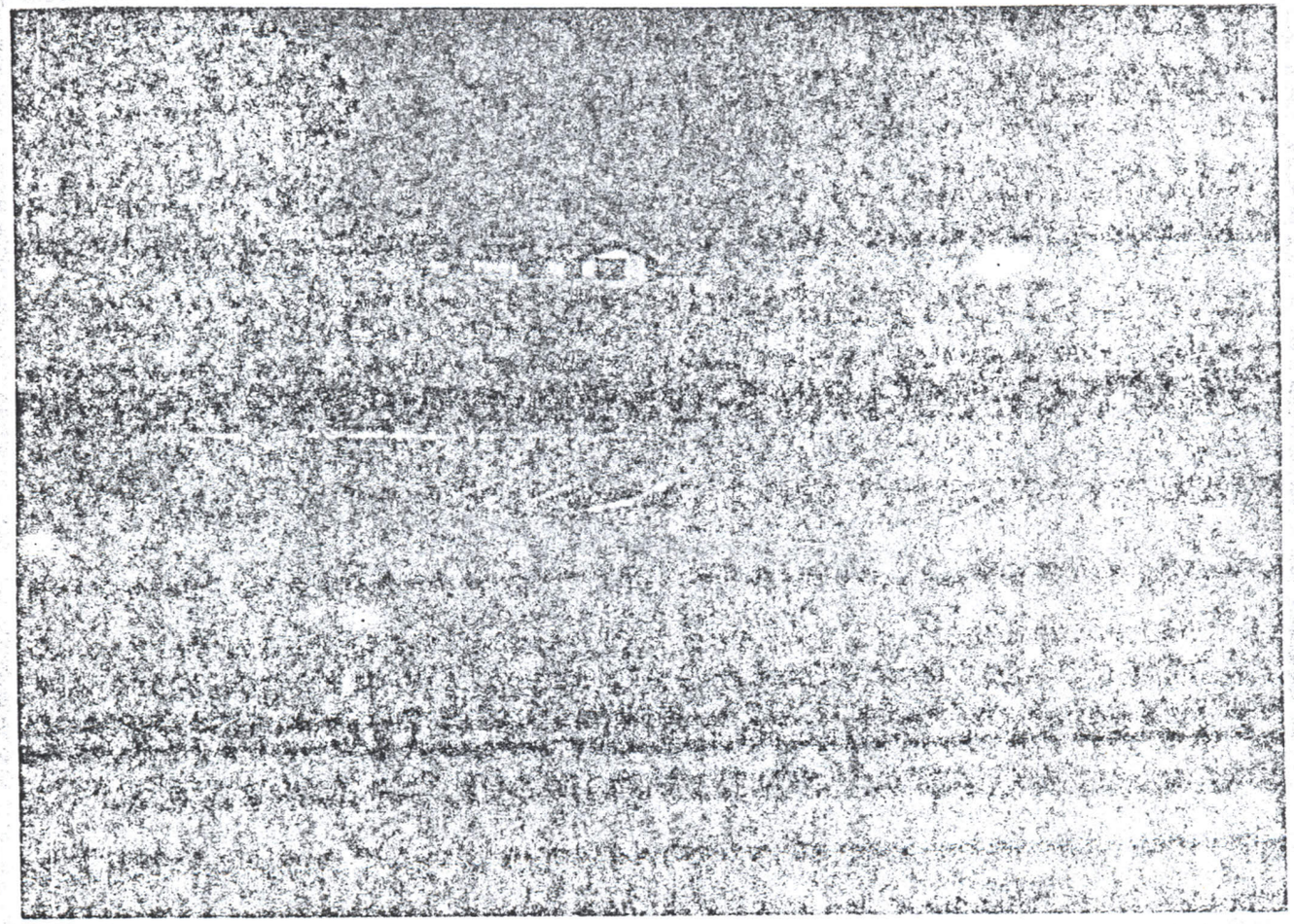
APPENDIX II

CABINET SOLAR DRYER CONSTUCTED ON CONCRATE FLOOR




182
145
20.8
15.2
44
44
44
5.1
10.2
120
RIGHT END VIEW
FRONT VIEW
LEFT END VIEW
BACK DOOR
120
400
520
FLAN

PHOTOGRAPH OF THE MODIFIED CABINET SOLAR DRYER CONSTRUCTED.



Appendix III: Itinerary of activities carried out during the mission

DATE	ACTIVITY
07/01/95 :	Departure from Accra to Kumasi.
07/01/95 :	Arrival in Kumasi.
09/01/95 : to 10/01/95	Purchasing of materials for solar dryer construction.
11/10/95 : to 20/01/95	Construction of cabinet solar dryer.
21/01/95 : to 23/01/95 :	Solar drying of meat strips and weather data monitoring.
24/01/95 :	Departure from Kumasi to Accra.