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Design of a small-scale solar Dryer to Improve Natural Drying of Vegetables and Fish

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ABSTRACT

This study aimed at improvement of a solar dryer based on the principle of natural–convection used for drying vegetables and fish. The constructed dryer, comprises of three main models, solar collector (tent of polythene sheet collector), drying chamber and solar chimney. Design has been made to eliminate the problem of quality loss and over drying. Okra, Tomato, onion, fish were subjected to solar drying and open – air drying processes. The chemical, microbiological analyses and sensory evaluation were carried out for the dried products. The results gives indication of improved quality for solar dryer compared to products dried in open – air systems which indicates its efficiency in drying.

Keywords: Drying, vegetables, fish, chemical composition, sensory evaluation.

INTRODUCTION

Drying is the oldest method of preserving food. The early American settlers dried foods such as corn, apple slices, currants, grapes, and meat. Compared with other methods, drying is quite simple. In fact, you may already have most of the equipment on hand. Dried foods keep well because the moisture content is so low that spoilage organisms cannot grow.

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The main purpose of drying is to preserve food by removing the water that is needed for microbial growth and enzyme activity. Drying also reduces the weight and bulk of foods for cheaper transport and storage. Dried food can have poorer nutritional and eating quality than corresponding fresh foods. So the correct design and operation of dryers are therefore needed to minimize quality changes to foods (Peter, 1997).

Sun drying is the old-fashioned way to dry food because it uses the heat from the sun and the natural movement of the air. But bright sun, low humidity, and temperatures around 100^0 F. are necessary. In some areas the humidity is usually too high for successful sun drying. This process is slow and requires a good deal of care. The food must be protected from insects and covered at night. Sun drying is not as sanitary as other methods of drying.

The solar tent dryer is made up of a polythene sheet worn over wooden frame. It works through evaporative drying using the green house principle. When set up in the sun, solar energy passes through the transparent polythene but gets trapped within it thereby raising the internal temperature. Cool air flowing in through an opening gets heated up and removed moisture from foods. This solar dryer speeds up the drying process considerably, resulting in a high quality product with extended shelf life. Even under high humid conditions, solar dryers could have other advantages such as :

(i) it can be kept in continuous operation even in raining weather

(ii) Drying in an enclosed environment protects the products from dust, dirt, affect by birds, rodents and insect infestation.

In the present study, a modified solar dryer was employed for drying certain vegetables and fish samples and comparing the characteristics of the dried products with those dried using a conventional open air drying process.

MATERIALS AND METHODS

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Low cost material (polyethylene) with high rigidity and long life has been used for construction of a solar dryer at the Department of Food Processing, Faculty of Engineering, Elimam El Mahdi, Sudan 2010. The metallic frame structure of dryer has been covered with polythene sheet. The polythene tent has a height of , in 2010 175 cm, top length of 180 cm and bottom length of 200 cm to fit over a metallic frame. The opening serves as air inlet into the solar tent and another, was made to serve as outlet of the hot air from the dryer. The frame work of the polythene tent is shown in Fig. (1).

Fig. 1. Polythene solar dryer

Drying methods

The product chosen for the study are likely to be dried in rural community of Sudan, they are okra (*H. Esculentus*), onion (*Alim cepa*), tomato and fish. Water fish “Bolti”

(Haplochromis) products were brought from areas on the white Nile further south at the Kosti town , during the months (March, May and August 2010).

Okra Drying

Young tender okra were preferred. Some samples were dried in whole, others in sliced 5mm thick (using hand slicer)

The pods were thoroughly washed and trimed. Discoloured and damaged tissues were isolated. After blanching, the product was washed with cold water. For preservative measures, okra pods were dipped for one minute in a solution containing 8000ppm sodium metabisulphite. The pods were then placed on trays inside the drying polythene dryer.

Onion drying

After the removing the tops (roots and outer leaves), the onion bulbs was washed and cut into slices 3mm thick and were directly used in the drying. Since blanching may destroy onions flavor, it was not applied. The use of preservative was not of necessity and therefore, after cutting, onion were evenly spread on trays and then into dryer.

Tomatoes drying

Tomatoes of good colour, ripen and frim were brought from market. After washing the tomatoes were cut into 6-9 mm thick. Then the slices were dipped for 3min in perspective solution containing 600ppm of SO_2 and 10%sodium chloride. Samples were then placed on trays and subjected to solar drying.

Drying of Fish

It was essential that before drying fish, should be prepared in a way which allows rapid salt penetration and water removal. Small and moderate sizes were preferred for drying, before drying inner membrane were removed and also the dark coloured blood. The samples were salted, then spread in trays inside the drying chamber and subjected to solar drying.

Characteristics of the dried, products

The quality characteristics of the dried products (vegetables and fish) using the two methods was determined using chemical and microbiological analyses as well as sensory evaluation.

Moisture content

The standard methods of the Association of Official Analytical Chemists (AOAC, 1984) was used to determine the moisture content of the samples in the present work. The samples were weighed into a pre-dried, weighed and clean porcelain dish. The samples were placed in an air – oven, cooled in a desiccator at room temperature and weighed. Moisture content of the samples were then calculated as follows:

$$\text{Moisture} = \frac{\text{Loss in moisture}}{\text{Weight of dried sample}} \times 100 \qquad (1)$$

Protein con

The analysis of protein contents of the sample was determined according to A.A.C.C method (1983) in which one gram of sample was digested by heating with concentrated sulphuric acid for 2½ hours in the presence of copper sulphate and potassium sulphate as digestion mixtures. After cooling the digest was diluted to volume of 100 ml with distilled water. Then,5 ml of the diluted water. Then, 5 ml of the diluted digest was transferred to clean steam distillation unit and 10 ml of 40% NaOH solution was poured into the distillation flask. The ammonia was distilled into a receiver flask containing boric acid solution. The ammonia trapped in boric acid solution was titrated directly with standard 0.1 N HCl solution using double indicator (Methyl red + Bromocressol green).

The change in colour of the mixture from blue to faint pink was taken as the end point. The crude protein value was calculated from the nitrogen content multiplied by a 6.25).×conversion factor (6.25), i.e., % crude protein = % (N

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The nitrogen content of the sample was calculated using the following expression.

(2)

$$N\% = \frac{\text{ml of HCl used in titration}}{\text{Aliquit of design taken}} \times \frac{\text{Normality of HCl}}{\text{Weight of sample taken}} \times \frac{\text{Volume up of the design}}{100} \quad (2)$$

Fiber content

Crude fiber (unavailable carbohydrates), were determined as described by the AOAC **(**1968**).**

Ash content

The method of AOAC (1984) was used to determine the ash content of the samples analyzed in this study. 2-3 grams of samples were weighed into a clean pre – dried and weighed porcelain dish.

The dish containing the sample was placed in a muffle furnace at 550°C and left burning for 5 hours at this temperature, then the dish with its contents were weighed again after cooling in a desiccator to room temperature. Ash content was calculated as follows:

$$\text{Ash (\%)} = \frac{W1 \times 100}{W2} \quad (3)$$

Where:

W1= weight of ash

W2= weight of sample

Micro-biological examination

Diluents and bacterial counts

Peptone water (0.1%) was used as a diluent .The dilution was prepared aseptically by adding 10ml sample to 90 ml of diluent to give 1:10 dilution v/v (Harrigan and Mc cance 1976).

Total viable count

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Total viable count per ml of sample was carried out by pour- plating of suitable dilution on melted nutrient a gar, and incubator aerobically after solidification at 370C for 72 hrs (Dirar,1976).

Mould and yeasts count:

Mould and yeast count was carried out according to Kregar and Vanrij (1984). PDA was used for count of diluted samples, 0.1ml were spreaded onto surface and incubated aerobically at 25 0C for 3 days and 10% tartaric acid solution was used adjust the pH of media to 3-5 ± 0.1 to suppress bacterial growth and to facilitate yeasts count.

Coliforms total count

Enumeration of coliforms was accomplished using the methods described by FAO(1992). One ml was added to test tube containing 9 ml Ringer solution to make 10-1 dilution. All decimal dilutions (10-2, 10-3,10-4) were prepared with 9 ml ringer solution plus 1 ml from previous dilution. All dilutions were shaken 25 times. Three tubes of Macconkey broth contained fermentation Durham tubes (for each decimal dilution) were inoculated. The tubes were shaken gently and examined for gas production and growth after 24h and if necessary after 48h.

Confirmation test for total coli forms

Each gassing tube of Macconkey broth was shaken gently, and aloofly of suspension was transferred to a tube of BEB broth. BGB tubes were incubated for 48 ±1 hr at 35 0C and then examined for gassing. The most probable number (MPN) was calculated based on confirmed gassing tubes 3 consecutive dilutions.

Enumeration of *Staphcococcus aureus*

One ml sample suspension for each dilution was transferred aseptically to 3 plates of Barid-parker agar medium. one ml of inoculum was distributed equitably to 3 plates (e.g 0.4ml,0.3ml and 0.3ml) and spread over the surface of the agar with sterile bent glass streaking rod. The plates were retained in upright position until inoculum was a absorbed

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by agar medium (about 10min). The plates were then inverted and incubated for 45-48 at 350C. Plates containg 20-200 colonies and having typical appearance of *S-aureus*

Sensory evaluation

Dried products developed (okra, Tomato, onion and fish) were assessed for product acceptability. The products were served to panels after drying. The products were assessed for colour, flavor taste, appearance and texture using a 9-point hedonic scale. The results were then statically analyzed (Larmond, 1982).

RESULTS AND DISCUSSION

Uses of solar driers have several potentially attractive features for aiding processing in tropical areas. They have no energy cost and may provide a potential method for drying foods. Their construction can be very simple, although relatively sophisticated designs

The solar dryer designed in the present study (Fig., 1) contains no mechanical parts, and it would clearly be attractive for use in small-scale fish or food processing. It could be, however, admitted that limited development work done so far on solar vegetable and fish driers has yet to demonstrate consistent advantages over conventional sun drying in a commercial situation.

Solar dryers employ some means of collecting and concentrating solar radiation to achieve elevated temperatures and reduce relative humidity during drying, this results in increasing drying rates, lower final moisture content and give high quality products.

Doe *et. al*. (1977) have pioneered the use of a simple tent of polythene sheeting supported on a bamboo frame. In Bangladesh improved drying times for fish were noted, as well as an inhibition of blow-fly larvae infestation due to the elevated temperatures.

Table (I) shows the mean temperature inside solar dryer and outside within the trial period. Temperatures for dry season (March, May) and a rainy month (August) were C for°C and 49°C, 39° recorded. Results show that temperatures in solar dryer were 50

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C were recorded for°C 35°C, 38°March, August and May, respectively. While 39 outside temperatures for the same months, respectively. Table (1) shows that solar dryer had high temperatures than the ambient temperature.

As for humidity, the lowest readings were obtained in the solar dryer and outside conditions. March and August have contracting humidity conditions in the study area because of the influence of rain in August and complete absence of rain in March.

Table1. Mean temperature history of experimental work inside and outside solar dryer

Date	Temperature inside the solar dryer and relative humidity		Outside temperature open air	
May	49	18.9%	35	72%
March	50	13.5%	39	26%
August	39	25%	38	70.8%

The present findings are in good accordance with the works of (Doe *et al*. 1977, who stated that "a temperature of 44-55 C could be achieved inside natural – convection C outside temperature. As shown in Table (2) and Fig.°solar dryer compared to 33-39 (2), a remarkably lower moisture content was noted for products used solar dryer (tent polythene sheet) compared to those using the open-air sun –drying. Also results from Table 2 show that drying times for onion were less than okra and drying time of tomatoes was larger than okra, this mainly due to the initial moisture content. With regard to the efficiency of the designed dryer, the inside temperature increased more than the out-side temperature.

Results showed that higher drying rates (shorter times) were obtained for products used polythene sheet, while longer times were obtained for open-air sun drying.

Table 2. Final moisture content and drying period of dried product using two methods of drying

Product	Solar drying	Sun-Drying

	Moisture period(hrs)	dryin	Moisture period (hrs)	Drying
Fish	14-16 %	50-72	25-29 %	74-120
Okra	7-9 %	17-22	13-15 %	48-72
Onion	4-6 %	16-23	7-8 %	50-74
Tomato	9-11 %	20-25	12-13 %	50-74

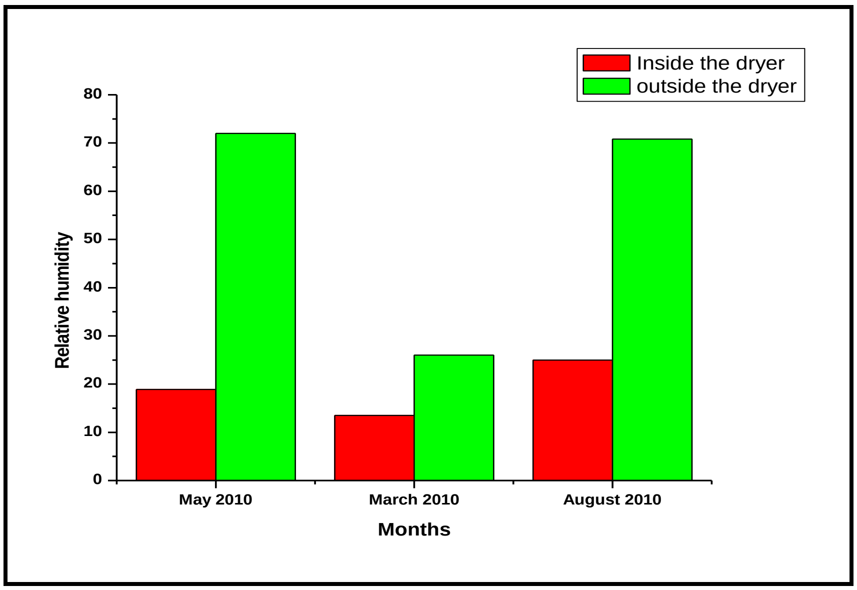

Fig. 2. Relative humidity inside and outside dryer

Chemical compostion

It was found that the moisture content of samples dried in polythene dryer were lower than those dried in open – air (Table 3). The high moisture content in open – air product deteriorates the product faster than polythene dryer product, this could be supported by works of Kofi (1992) who stated that " product with high moisture content tend to deteriorate faster than dried product.

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The result in Table (3) indicated that products dried in polythene dryer were higher than those of the products dried in open – air dryer, or there is no markable difference in protein quantities in both samples used polythene dryer, and those dried in open – air.

Table (3). Comparable approximate composition of solar drier and open air sun-dried

Commodity	Moisture (%)	Crude Protein (%)	Crude Fibre (%)	Ash (%)
Fresh Fish	72.5	19.2	-	1.2
Sun – dried Salted fish	24.9	54.8	-	8.9
Solar – dried salted fish	14.9	62.2	-	8.0
Fresh Okra	87.1	3	0.92	1.19
Sun – dried Okra	13.2	10.2	10.5	11.99
Solar dried Okra	8.9	14.1	13	9.11
Fresh Onion	89.2	1.3	0.2	0.7
Sun – dried Onion	9.1	3.2	6.9	2.5
Solar dried Onion	5.2	3.5	8.3	2.0
Fresh Tomato	94.0	1.2	0.3	0.6
Sun – dried Tomato	11.1	9.0	1.6	5.9
Solar dried Tomato	9.0	10.0	1.6	4.9

Ash content in Table (3) show that there were remarkable differences in ash content in samples dried using solar dryer (polythene) and those dried in open – air. The high levels of ash in open – air product could be attributed to dirt and sand contamination in open – air sun drying.

Microbiological Characteristics

Total viable count of dried samples is shown in Table (4). The sun dried products in open-air exhibited the higher initial microbial load, compared with samples dried with ten polythene dryer which exhibited the lower microbial load, this mainly due to the fact that, these products were exposed to open –air with free access to all sources of contamination such as dusts, dirt, flies, blown debris, whilst polythene dried products were protected from all these sources of contamination mentioned above. It is known that most intestinal pathogenic bacteria such as *Cholera*, Dysentery and Typhoid, die if they are exposed to

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temperature 50-66 for certain time (45-60-75-90 minutes) and as indicated by results from this study, solar drier achieved temperature of 34-50C0, this means that most of these pathogens would die in solar thus it proves that solar dryer reduced the contamination of food stuff.

Table 4. Micro-biological Examination(C.f.u/ml)

Products	Solar dried				Open-air dried			
	T.v.c	coliform	y,m	staph	T.V.C	coliform	y,m	staph
Okra	ND	20X103		102x2	6x102	ND	20X104	
Onion	2X102				2X103			
Tomatoes	102	ND		50X103	5x102	ND	60X106	
Fish	1X102				3X104			
	102x3	ND	10X103		9x102	ND	4x105	
	1.5X102				2x103			
	102x2	ND	20X103		6x102	ND	60X103	
	2X102				20X104			

ND = Not detected
T.V.C= Total bacterial count.
Y,m= Yeast and moulds.
Staph= Staphylococci.

Sensory evaluation

The consumer is the final key for understanding quality. Solar dried products showed higher sensory scores (Table 5`) for all sensory attributes. Such as colour, texture, appearance, flavor, odour and taste and over all acceptance. An interesting finding from the present study, showed that the polythene products were of better qualities in terms of colour ,texture , appearance flavor, odour and taste than open air products. This superior improvement mainly returned to the effect of pre-treatment (sodium metabisulphite for okra, and SO_2 for tomatoes) .All this supported by the work of FAO (1992).

Table 5a. Results on acceptability evaluation score in solar dried and sun dried products.

Sample	Appearance	Colour	Texture	Odour	Taste	Flovour
Solar dried okra	8.6	8.7	8.3	8	8.2	8.3
Sun-dried okra	6.6	6.5	6.9	6.2	6.5	6.4
Solar dried onion	8.8	8.4	8.4	8.2	8.3	8.6
Sun dried onion	7.9	7.2	7.3	7.2	7.4	7.2
Solar drier tomatoes	8.9	8.5	8.3	8.2	8.3	8.4
Sun dried tomatoes	6.5	6.3	6.2	6.4	8.2	6.5
Solar dried fish	7.7	7.5	7.3	7.2	7.3	7.2
Sun dried fish	5.2	5.3	5.2	5.5	5.6	5.7

Table (5b) appearance of both products dried in the solar dried and products dried in open-air

Product	Observation		
	Colour	Texture	Flavour
Solar dried okra	Green	Firm	Sweat
Sun dried okra	Brown	Brittle	Fair sweet
Solar dried onion	Willits	Brittle	Pungent
Sun dried onion	Brown	Crisp	Pungent
Solar dried tomatoes	Red	Brittle	Very sweet
Sun dried tomatoes	Brown	Very brittle	Sweet
Solar dried fish	White	Hard	Slight rancid
Sun dried fish	Brown	Toughen	Rancid odours

CONCLUSION

The advantages of the small scale solar dryer, developed in this investigation are summarized as follows:

1. It is no energy cost.
2. It is construction can be very simple.

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3. Design having no mechanical parts to break down have been used.
4. Materials used in its construction were locally available.
5. It can be utilized for drying different agricultural crops, meat and fish.

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