Vol.9, No.3, pp., 10-20, 2021

ISSN -2055-0197(Print),

ISSN 2055-0200(Online)

DEVELOPMENT OF RENEWABLE ENERGY FARM PRODUCE DRYING SYSTEM USING SOLAR COLLECTOR

Umukoro, E [1]., Alebu, O [2]., Efosa, J [3]. and Odion-Ewasi, E [4].

[1, 2] Department of Science Laboratory Technology, Auchi Polytechnic, Edo State.

[3] Department of Physical Science Laboratory Technology,Auchi Polytechnic, Edo State.

[4] Department of Food Science Technology, Auchi Polytechnic, Edo State.

ABSTRACT: *The renewable energy farm produce dryer is a system which will remove moisture from farm produce in the farm yard. This system will use solar collector to harness energy from the Sun and concentrate it on a drying chamber to remove moisture from the farm produce such as plantain, tomatoes and pepper. The farm dryer have two compartments system. Firstly, heat chamber. The heat chamber is made up of a solar glass collector, reflector foil and a rectangular wooden box. This chamber converts the Sun energy to heat energy. It is mounted at angle of 60^o to the drying chamber. Secondly, the drying chamber. The drying chamber comprises of a cuboids, tray and isolating material. This is the chamber where the farm produce is laid and removal of moisture takes place. The heat chamber has an opening at the junction of interface between the heat chamber and drying chamber. This opening allows the flow of heated air mass from the heat chamber into the drying chamber. This system will enable farmers to dry perishable farm produce in the farm yard and preserved farm produce which have off-season to consumers. This will help to reduce food shortage and hike in the cost of such food items.*

KEYWORDS: closed system, heat energy, solar energy, solar collector, insulator , reflector.

INTRODUCTION

Farming contributes ninety-five percent of the food consumed by the citizen of a Nation. Most of the farm produces are perishable and this makes the produce unfit for consumption when eventual it gets to the consumer. Farming is carried out in rural area which is a distance from the urban settlement where most of the produce is consumed. There are no good roads and inadequate transportation system to carry harvested farm produce from the farm yard to market places. Also, farm produce is seasonal and this makes the produce unavailable for the consumers all through the year. This has made farmer to cultivate for themselves and their family. This type of farming practice has led to food shortage and causes increase in the cost of farm products. All

@ECRTD-UK- https://www.eajournals.org/
ULR: https://doi.org/10.37745/ijeer.13

Vol.9, No.3, pp., 10-20, 2021

ISSN -2055-0197(Print),

ISSN 2055-0200(Online)

the same, the shortage of food will lead to starvation and malnutrition of the citizen if proper measure is not taken. Therefore, there is need to design and construct a renewable energy farm produce dryer device which will enable farmers dry their farm produce and preserve it for further purpose. The energy from the Sun reaches the earth's surface through electromagnetic radiation. The radiation beam will be collected to generate heat energy. This energy in form of heat will be concentrated towards a drying chamber where farm produce is place to reduce their water content. The system will be install in the farm yard and will prevent the farm produce from perish/spoilage. It will also prevent food contamination and control spread of diseases on consumable farm produce.

Concept of solar energy

Solar energy is quite simply the energy produced through a thermonuclear process directly by the sun. The process creates heat and electromagnetic radiation. The heat remains in the sun and the electromagnetic radiation in the form of visible light, infra red light, and ultra-violet radiation streams out into space in all directions. Small fraction of the total radiation produced reaches the Earth. The Sun radiation that reaches the earth is the indirect source of nearly every type of energy used today. Two essential components are required to store and convert solar energy to usable energy form. These are the collector and storage unit. The function of the collector is to collects the radiation that falls on it's surface and convert almost all to a required form of energy. The storage unit stores all the converted energy for use when the energy source is not available at night or when energy absorbed by the collector is less.This storage unit is essential because of non constant nature of solar radiation. There are three types of collectors namely; the flat plate collectors, focusing collector and passive collector and many varieties of storage units.

Drying principle

When hot air is circulated over a moist produce, the heated air removes moisture from the produce until the hot air is fully saturated i.e. means absolute humidity has been reached. The rate of moisture removal depends on the temperature. The higher the temperature, the higher the heat generated and the increase in the moisture removal from the sample. If the air is warmed and the moisture contain in the sample remains the same, but the relative humidity falls so the air removes more moisture from the produce. For achieving a better result economically, the drying rate must be high but without using excessive heat which tends to degrade the farm produce. In the drying process heat is required to evaporate moisture from the farm produce and air-circulation flow is required to carry away the evaporated moisture. There are two basic mechanisms during the drying process;

i. Migration of moisture from interior surface to outer surface.
ii. Evaporation of moisture from outer surface to the surrounding.

@ECRTD-UK- https://www.eajournals.org/
ULR: https://doi.org/10.37745/ijeer.13

Vol.9, No.3, pp., 10-20, 2021

ISSN -2055-0197(Print),

ISSN 2055-0200(Online)

METHODOLOGY

The renewable energy farm produce dryer was designed and constructed using a transparent glass solar collector to absorbed Sun rays. The rays are directed to aluminum film which is than heated up. The air at the surface of the aluminum film is hotter than the incoming air rays. Therefore, the hot air is forced into an opening at the end of the heat chamber into the drying chamber. The drying chamber is made of a wooden-cuboids with an aluminum film and a stainless wire gauze. The farm produce samples are plantain and yam. The samples spread on the wire gauze inside the drying chamber. The dryer removes the moisture content of the harvested farm produce for preservation and storage. The dryer comprises of two units; the heat concentration chamber and the drying chamber. The heat concentration chamber is made of wooden box of area (46 inch x 21 inch x 8 inches). The upper part is mounted with the transparent glass collector. The glass collector collects the infrared rays from the electromagnetic radiation components which are mostly transmitted in form of heat with wavelength greater than that of visible light. Inside the wooden box contains an aluminum film which is coated with black colour. This serves as a heat absorber and good conductor of heat. The collision of the air particles trapped inside the box increases the average kinetic energy of the molecules and hence increases the heat inside the box. The heated air inside the box is less dense than the incoming sun rays. Hence the heated air is forced by convection through the small opening at the upper end of the box into the drying chamber. The second unit is the drying chamber. This is made of a cuboids of length 33 inches x breadth 22 inches x height 34 inches and it surface is covered with an aluminum film. It contains the wire gauze slots where the test sample is laid. The wooden material serves as an isolator between the drying system and the surrounding.

Heat generating chamber

The heat generation chamber is made up of a wooden material of area 46 inches x 22 inches x 8 inches. The inside of the box is covered with aluminum film plate and coated with black as shown in figure 1. The upper end of the heat generating chamber is covered with a glass solar collector of area 21 inches x 44 inches x 5 mm. The heat box chamber is tilted at an angle of 60 ^{o} to the vertical. The glass is aligned horizontally across the East and West margin to allow direct rays on the surface of the collector. The effective area of the collector is 462 inches. The glass solar collector absorbs the radiation from the Sun and incident it on the black smooth surface of the aluminum film plate. The trapped air closed to the aluminum surface inside the box is hotter than that far from the surface, hence the hotter air is forced to move by convection through an opening of area 18mm^2 in the upper end of the heat chamber to the drying chamber. The aluminum film serves as good heat conductor.

@ECRTD-UK- https://www.eajournals.org/
ULR: https://doi.org/10.37745/ijeer.13

Vol.9, No.3, pp., 10-20, 2021

ISSN -2055-0197(Print),

ISSN 2055-0200(Online)

Figure 1: Heat concentration box

Figure 1a:: Coated heat concentration chamber

Drying chamber

The drying chamber together with the structural frame of the dryer was built from well-seasoned woods which could withstand termite and atmospheric attacks. The cuboids chamber is made up of area of 33 inches x 22 inches x 35 inches. The inside of the dryer is covered with an aluminum film plate which distributes the heated air uniformly for the farm produce. The lower end of the drying chamber contains an opening area of 22 inches x 10 inches. This is the portion where the heat concentration box is inserted into the drying box. The chamber also consists of a drying wire mesh which is framed with aluminum sheet of area 22 inches x 22 inches. An access door is made on the drying chamber at the back view of the cuboids. The door will enable the farmer inserts the farm produce's samples in the dryer. The door is lagged with wooden material to prevent the system against heat loss from the chamber to the environment. The front and back views of the drying chamber box are shown in figure 2

@ECRTD-UK- https://www.eajournals.org/
ULR: https://doi.org/10.37745/ijeer.13

Vol.9, No.3, pp., 10-20, 2021

ISSN -2055-0197(Print),

ISSN 2055-0200(Online)

Figure 2b: Dryer back view

Glass solar collector

The solar collector is made of glass with diameter/thickness of 5 mm^2. This is a transparent material which absorb all the radiation falling on it's surface. The collector is made of an area of 48 inches x 22 inches. The higher the diameter/thickness of the glass the higher it absorption rate. The collector is framed with an aluminum and a rubber isolator as shown in figure 3.

Figure 3: Glass solar collector

Drying Tray

The drying trays are contained inside the drying chamber and were constructed from a double layer of fine chicken wire mesh with a fairly open structure to allow hot air to absorb the moisture of the sample of the farm produce.

Electronic measurement

The measurement of samples content was carried out using an electronic weighing device as shown in figure 5(a-b). The weighing instrument was used to determine the weight of the yam and plantain samples content before and after drying. This instrument was used to ascertain

@ECRTD-UK- https://www.eajournals.org/
ULR: https://doi.org/10.37745/ijeer.13

actual value reading of sample's content and minimizes uncertainty of recording value which might result from human error.

Figure 5a: Yam mass content

Figure 5b:Plantain mass content

RESULTS AND DISCUSSION

The constructed solar collector farm produce dryer was installed as shown in figure 5. The farm produce that was used for testing the dryer are yam and plantain as shown in figure 6(a-b). The mass weight of the yam and plantain before drying was 888.5 g and 459.0g.The farm produce were dried for three days during the wet-season in the month of May and during the dry-season in the month of November 2021. The moisture content loss was determined using the formula;

$$M_c = \frac{M_f - M_d}{M_f} \times 100$$

where

M_c = moisture content of the sample (%)

M_f = Mass of fresh sample (g)

M_d = Mass of dried sample (g)

Vol.9, No.3, pp., 10-20, 2021

ISSN -2055-0197(Print),

ISSN 2055-0200(Online)

Figure 5: Complete installation of solar renewable farm produce dryer

Figure 6a: Yam slice

Figure 6b: Plantain slice

Table 1: Dried sample weight in the month of May 2021

	Yam weight (g)	Plantain weight (g)
Day 1	622.5	331.5
Day 2	455.5	288.5
Day 3	134.2	108.4

Table 2: Dried sample weight in the month of November 2021

	Yam weight (g)	Plantain weight (g)
Day 1	520.1	204.3
Day 2	213.2	86.2
Day 3	92.4	41.1

Calculation;

Moisture loss from yam and plantain in the month of May give;

$$M_y = \frac{888.5 - 134.2}{888.5} \times 100$$

@ECRTD-UK- https://www.eajournals.org/
ULR: https://doi.org/10.37745/ijeer.13

Vol.9, No.3, pp., 10-20, 2021

ISSN -2055-0197(Print),

ISSN 2055-0200(Online)

$$= \frac{754.3}{888.5} \times 100$$

$$= 0.8489 \times 100$$

$$= 85\%$$

$$M_P = \frac{459 - 108.4}{459} \times 100$$

$$= \frac{350.6}{459} \times 100$$

$$= 0.7638 \times 100$$

$$= 76\%$$

Moisture loss from yam and plantain in the month of November give;

$$M_y = \frac{888.5 - 92.4}{888.5} \times 100$$

$$= \frac{796.1}{888.5} \times 100$$

$$= 0.896 \times 100$$

$$= 90\%$$

$$M_P = \frac{459 - 41.1}{459} \times 100$$

$$= \frac{417.9}{459} \times 100$$

$$= 0.91 \times 100$$

$$= 91\%$$

ULR: https://doi.org/10.37745/ijeer.13

Vol.9, No.3, pp., 10-20, 2021

ISSN -2055-0197(Print),

ISSN 2055-0200(Online)

Table 3: Analyzed proximate composition and mineral content of fresh/raw yam and plantain

Minerals	Yam (%) per 100g	Plantain (%) per 100g
M/C	89.85	45.90
Fat	0.32	2.92
C/P	4.12	13.70
Ash	2.80	1.80
C/Fiber	1.01	3.81
NFE	83..40	67.90
K(mg/Kg)	0.33	256.00
Ca(mg/Kg)	0.05	136.00
Mg(mg/Kg)	0.20	389.00
P(mg/Kg)	0.10	214.00
Fe(mg/Kg)	1.00	3.63
N_a(mg/Kg)	0.02	239.00

Table 4: Analyzed proximate composition and mineral content of dried yam and plantain in the month of May

Minerals	Yam (%) per 100g	Plantain (%) per 100g
M/C	9.52	10.80
Fat	0.35	2.90
C/P	4.10	13.60
Ash	2.70	1.80
C/Fiber	1.00	3.80
NFE	83.35	67.90
K(mg/Kg)	0.33	256.00
Ca(mg/Kg)	0.05	136.00
Mg(mg/Kg)	0.20	389.00
P(mg/Kg)	0.10	214.00
Fe(mg/Kg)	1.00	3.63
N_a(mg/Kg)	0.02	239.00

@ECRTD-UK- https://www.eajournals.org/
ULR: https://doi.org/10.37745/ijeer.13

Vol.9, No.3, pp., 10-20, 2021

ISSN -2055-0197(Print),

ISSN 2055-0200(Online)

Table 5: Analyzed proximate composition and mineral content of dried yam and plantain in the month of November

Minerals	Yam (%) per 100g	Plantain (%) per 100g
M/C	8.50	10.00
Fat	0.35	2.90
C/P	4.10	13.60
Ash	2.70	1.80
C/Fiber	1.00	3.80
NFE	83.35	67.90
K(mg/Kg)	0.33	256.00
Ca(mg/Kg)	0.05	136.00
Mg(mg/Kg)	0.20	389.00
P(mg/Kg)	0.10	214.00
Fe(mg/Kg)	1.00	3.63
N_a(mg/Kg)	0.02	239.00

Keys;
M/C = moisture content
C/P = crude protein
C/F = crude fibre
NFE = nitrogen free extract

DISCUSSION

The developed solar dryer performance was evaluated using yam and plantain as harvested farm produce. During rainy season in the month of May as shown in table 1, the mass of the of yam and plantain sample after drying in the developed dryer for three days were 134.2g and 108.4g. Also, during the dry season in the month of November, the mass of the samples after drying for three days were 92.4g and 41.1g as shown in table 2. From these data, it shows that there is more radiant energy in the month of November than that of May. Hence, more heat is generated by the heat concentration chamber as the Sun rays fall on the glass solar collector during the dry season compared to the wet season. Therefore, the removal of moisture from the plaint and yam is higher in the month of November compared to the month of March. In addition, the analyzed nutrients for fresh/raw yam and plantain as shown in table 3 is the same as that of wet and dry season as shown in tables 3,4 and 5. This shows that the food nutrients of the farm produce are not lost during the drying process using the developed system but the moisture content of the yam and plantain were reduced to 9.52% and 10.9% as shown in table 4 and 8.5% and 10% depicted in table 5. From this data, it shows that the plantain and yam can be preserved for a very long period of time.

@ECRTD-UK- https://www.eajournals.org/
ULR: https://doi.org/10.37745/ijeer.13

Vol.9, No.3, pp., 10-20, 2021

ISSN -2055-0197(Print),

ISSN 2055-0200(Online)

CONCLUSION

The developed farm produce solar dryer have high performance for heat generation and absorption when exposed to solar radiation. The moisture content of the farm produce is reduced to a minimal percentage without causing any damage to the nutrient content of the harvested crops. This system can be employ in the farm yard for crop drying by farmers to prevent spoilage of perishable farm produce before it gets to the consumers in urban area. The dried farm produce is free from dust particles which might cause diseases on the food crops and rodent attacks crops.

Acknowledgement

We want to appreciate TETFund for given us the opportunity to carry out this research work and providing the financial support for the completion of the research.

References

Andritsos, N., Dalampakis, P. and Kolios, N. (2003), Use of Geothermal Energy for Tomatoes Drying. Oregon Institute of Technology, Geo-heat Center bulletin, 24(1); 1-9.

Akachukwu, B.E. (2014), Investigation of Low Cost Solar Collector for Drying Vegetables in Rural Areas. *Agric. Eng. Intl. Journal*, 16(1);118-125

Barrett, D.M. and Latapi, G. (2006), Tomatoes Attributes and their Correlation to Peelability and Product Yield. *Journal of the Science of Food and Agriculture*, 54(2); 65-73.

Bolaji1, B.O., Olokode, O.S and Olalusi, A.P. (2008), Development of a Wind-ventilated Box-type Absorber Solar Air Collector. *Asset international journal*, 7 (1): 18-29.

Chand, T.k, Mohanty, M.K and Mohanty, R.C. (2015), An Overview of Solar Energy and its Application in Solar Dryers with Brief Concept of Energy and Energy Analysis. *International journal of Research*, 2(1); 870-875.

Forson, F. K., Nazha, M. A. A., Akuffo, F. O. and Rajakaruna, H. (2007), Design of Mixed-mode Natural Convection Solar Crop Dryer; Application of Principles and rules of thumb. *Renewable energy*, 32(14); 2306-2319.

Jithinraj, T. and Aftab, A. K. (2014), Experimental Analysis on Multi Pass Flat Plate Collector Solar Air Dryer. International Journal of Engineering Engineering Research and Technology, 2(7); 1-11.

Okonkwo, W.I. and Okoye, E.C. (2005), Performance Evaluation of a Pebble Bed Solar Crop Dryer. *Nigerian Journal of Technology*, 24(2): 68-73.

Santos, B.M., Queiroz, M.R. and Borges, T.P.F. (2005), A Solar Collector Design Procedure for Crop Drying. *Brazilian Journal of Chemical Engineering*, 22(2); 277-284.

Selvaraj, M. and Sadago, P. (2017), A Review of Solar Energy Drying Technology with Air Based Solar Collector. *Advances in Natural and Applied Science*, 11(4); 472 – 478.

@ECRTD-UK- https://www.eajournals.org/

ULR: https://doi.org/10.37745/ijeer.13