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PERFORMANCE OF DIRECT CONCENTRATED SOLAR THERMAL COOKING FUEL AT THE PEAK OF RAINY SEASON FOR KADUNA RESIDENTIAL BUILDINGS

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ABSTRACT

Direct concentrated solar thermal is the most sustainable cooking fuel with an edge over photovoltaic which depends on collection storage and conversion to electric energy and later to heat energy, at this stage it takes the non sustainability element of electricity. Concentrated solar thermal is the cheapest source of cooking fuel in sun rich areas with vast advantages: cooks meal up to a high temperature without burning the menu and vitamins, and food does not stick on pot. The hindrance of it acceptance and spread is not only the inability to cook at night but also in bad weather such as: dusty atmosphere, clouds and precipitations. This paper aims at assessing the effectiveness of this cooking fuel during rainfall in Kaduna town. It carried out a literature review of the climatic elements from January to December and found August to be the peak of the rainfall with lowest hourly sunshine and solar radiation. It furthered performed a cooking experiment from the 1st to the 31st of August 2017, during this period a primary data of the hourly sunshine was recorded by direct observation. The findings showed the minimum hourly sunshine received during this period contains enough radiation for cooking. It is therefore concluded that the rainy season at its peak with clouds and high humidity in Kaduna town still receives enough sunshine as a cooking fuel for it dwellings. It is therefore recommended architect to implement the direct capturing of the sunray as a cooking fuel in residential buildings

KEYWORDS: cooking fuels, Kaduna city, solar thermals, residential buildings, weather.

I. INTRODUCTION

Kaduna city is located in Northern Nigeria were basic households cooking needs are almost entirely dependent on fuel wood or use as a supplement of other cooking fuels (Ali & Richard, 2010). Baiyegunhi and Hassan (2014) found the decisions on this dependency are rooted on household head's age, educational attainment, household size, income, type of dwelling unit, the duration of food cooked and price of fuel wood. Amod, Kirk, Asheena, Amar and Michael (2005) and Baiyegunhi and Hassan (2014) observed that these have adverse effects on households' health, productivity and environmental degradation; therefore the need for a cheap abundant and more sustainable cooking fuel.

Kaduna town with coordinates of 10° 36' 33.5484" N and 7° 25' 46.2144" E falls within the world area (30^0N and 30^0S), this according to and Omonijo, 2014 Sheyin, 2005 has enough solar radiation for effective performance of solar thermal energy for solar cooking. Solar thermal energy as a cooking fuel is used in two forms: the Concentrated Solar Thermals (CST) and Photovoltaic (PV). The PV is a process of collecting solar radiation through panels this is either used directly after converting it to electricity or stored and later. CST is direct use of solar radiation as heat energy as a cooking fuel (Kalogirou, 2004; Boumann, 2017). Concentrated Solar Thermal as a cooking fuel is sorely dependant of sunshine and solar radiation; this in turned is dependant of an atmosphere free of wind, dust, clouds, high humidity and precipitations (Carmel, 2013; Zhang, Shen, Hong, Wang & Yang, 2015).

A hindrance is experience if the above elements dominate the atmosphere, hence, cooking is impossible. This is one of the challenges that hinder the spread and incorporation of this cooking fuel in residential dwellings this study looked into the possibilities receiving enough radiation during these periods through the following objectives: 1. To identify periods law solar radiation and sunshine in Kaduna within the year, 2. To find the

effectiveness of the amount of sunshine within these periods, 3. To experiment the ability of solar cooking from the sunshine received during this periods.

II. METHODOLOGY

This paper made a literature review of the climatic elements of Kaduna city to find the period(s) when solar radiation and sunshine are low due to hindrance of climatic elements and their products. It also by personal observation collected a primary data of the hourly sunshine received during the period(s) and to perform an experiment during the same period(s) using a box solar cooker produced by the author to assess the effectiveness of cooking of the solar radiation contained in the hourly sunshine received during such period.

Objective 1

To identify periods law solar radiation and sunshine in Kaduna within the year

The climatic data of Kaduna city in Table 1 were analysed to determine the periods within the year with elements that obstruct solar radiation and sunshine, these were during the affected periods as in Table 2.

The harmattan season starts from November to February with the entire atmosphere covered with dust particles despite a cold daily temperature the solar radiation is high creating hotter afternoons with high sunshine from the 10:00am to 4pm. Carmel (2015) a windy situation is experienced which can also have an adverse effect on solar radiation. However this period is known for its cold evenings and hot afternoons with a high sunshine and solar radiation due to zero precipitation as indicated in Table 1.

The hot season ranges from late February to May which is notable of high temperature and solar radiation from morning to evening this does not pose any hindrance to the use of solar thermal cooking fuel since cooking periods are within the hot afternoons. The rainy season is a period from June to early October when clouds and precipitations are prominent, with constant appearance and disappearance of clouds and rain creating cloudy scenarios and clear blue sky respectively. The little intervals of clear sky can give effective solar radiation and brighter sunshine. This is the period where the challenge of the sunshine and solar radiation is most experienced hence a likely challenge to the use of solar thermals.

Table 1: Average Monthly Climatic Data of Kaduna City for the Period of 1995-2016

MONTH	RAINFALL MM	HUMIDITY	TEPMT ^{0}C	WIND M/S	SUNSHINE HR	SOLAR RADITON W/m2
NOV	0.0	41.1	33.0	6.3	9.50	9.5
DEC	0.0	30.3	28.6	5.5	9.50	8.5
JAN	0.0	28.8	34.3	6.8	9.00	6.4
FEB	0.0	24.4	34.7	5.6	9.00	8..1
MAR	7.7	26.7	36.9	5.3	8.60	7.0
APR	50	47.5	35.7	7.3	8.06	7.4
MAY	125.4	69.1	33.0	8.7	7.80	6.5
JUN	179.8	75.2	30.6	8.0	7.20	5.4
JUL	263.5	78.7	29.2	7.1	5.00	5.1
AUG	299.7	82.3	28.4	7.9	3.90	4.44
SEP	204.6	78.1	30.0	7.9	5.70	5.6
OCT	78.6	71.7	31.66	7.1	8.00	7.0

Harmattan: cold, windy Hazy, dusty
Hot, dry
Precipitations clouds

Source: Boumann (2017)

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Table 2: Periods and obstacles to Solar Energy within the year in Kaduna

Source: Author's work (2017)

PERIOD	HINDRANCE	SUNSHINE	SOLAR RADIATION
November	Hamattan season Dust, wind	9.5	9.5
December		9.5	8.5
January		9.00	6.4
July	Wet season: clouds	5.00	5.1
August	rainfall	3.90	4.44
September		5.70	5.6
June		7.20	5.4
February	Dry season	9.00	8..1
March	No hindrance	8.60	7.0
April		8.06	7.4
May		8.60	7.0

Objective 2

To find the effectiveness of the amount of sunshine within these periods

Sunlight carries the "fuel"(Solar Radiation) of all solar energy systems and the performance of solar thermal systems depend on the availability and intensity of sunlight received. Clouds have a big impact on the amount of solar radiation reaching the surface of Earth. According to Dino (2012) clouds reflect and absorb a significant part of the incoming solar radiation, on average and clouds absorb or scatter about 20% of the incoming solar radiation.

Objective 1 revealed that the lowest radiation received in the month of August and this seems to be the peak of the bad weather during the year. The sunshine received was observed hourly overlooking the pockets of opening during cloud formations and movements. The sunshine received during the month of August 2017 is expressed in Table 3, this shows the total hours sunshine received and total hours received during cooking effective periods from 10:00am to 4:00 pm (Solar Cooker at Cantinawest [SCC], 2015) each day from the 1st of the month to the 31st.

Table 3: Period of Hourly Sunshine in the Month of August 2017

	7am	8am	9am	10am	11am	12am	1pm	2pm	3pm	4pm	5pm	6pm	TOTAL HRS	EFFECTIVE HRS	Type of food cooked	
															lunch	Dinner
1	■	■	■	■		■	■	■	■	■	■	■	11	6	RB	RB
2	■	■	■	■	■	■	■	■	■				9	6	RB	RB
3				■	■	■	■	■	■				6	6	RB	RB
4				■	■	■			■	■	■	■	7	5	RB	RB
5	■	■	■	■	■	■				■	■	■	9	4	RB	R
6					■	■	■	■	■	■	■	■	8	6	RB	RB
7					■	■	■	■	■				5	5	RB	RB
8		■	■	■	■	■	■	■	■	■	■	■	11	7	RB	RB
9								■	■	■			3	3	-	RB
10					■	■	■	■			■	■	6	4	RB	-
11			■	■	■	■	■	■	■	■	■	■	10	7	RB	RB
12							■	■	■				3	3	-	RB
13						■	■	■	■	■			5	5	-	RB

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14	4	2	-	R
15	5	4	RB	-
16	4	3	RB	-
17	4	3	-	RB
18	12	7	RB	RB
19	7	6	RB	RB
20	7	5	-	RB
21	9	7	RB	RB
22	4	4	RB	-
23	9	7	RB	RB
24	12	7	RB	RB
25	5	5	R	RB
26	5	5	RB	RB
27	7	5	RB	RB
28	5	5	RB	R
29	6	3	RB	-
30	3	3	-	RB
31	9	7	RB	RB

HOURLY SUNSHINE
SLOR RADIATION EFFECTIVE PERIOD
R
B STACK RICE AND BEANS
R RICE ONLY

Source: Author's Fieldwork (2017)

Objective 3

To experiment the ability of solar cooking from the sunshine received during this periods.

An experiment was therefore carried out during this month from 1st to 31st August to find the possibility of cooking with the little radiation and sunshine received. The hourly sunshine observed in Objective 2; Figure 4 was done concurrently with the solar cooking experiment conducted by the Author.

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In this experiment:

1. A box solar cooker without lid to avoid constant turning towards the sun direction was used
2. The cooking was done outdoor with glass casing or coverage of the box cooker in form of a house, since the indoor cooking depends on the same environmental and climatic variables.

Rice and hard beans were used (stacked) as menu for all the cooking because they take up to 2 to 3 hours to cook as earlier experiment by the author in Table 4. These two menus were place side by side (stacked) in the same cooker.

Table 4: Average Sunshine needed for Cooking Meals in the Month of August

S/N	MEAL	HOURS OF SUNSHINE
1	BOIL EGG	30- min
2	INDOMIE	30m
3	BOIL YAM	1hour - 1hr 30min
4	BOIL RICE	1,5hr – 2hrs
5	BREAN (HARD)	2hrs – 3hrs

Source: Boumann (2014)

Table 5: Analyses of the Effective Period of Cooking (10:00am to 4:00pm) for the Month of August 2017

		LUNCH		DINNER	
S/NO	DATE	RICE /BEANS 3HRS	RICE/ ONLY 2HRS	RICE /EANS 3HRS	RICE /ONLY 2HRS
1	1,2,3,4,6,7,8,11,18,19,21,23,24,26,27 and 31	YES	-	YES	-
2	5 and 28	YES	-	-	YES
3	25 0nly	=	YES	YES	-
4	10,15,22, and 29	YES	-	-	-
5	10,15,22, and 29	-	-	YES	-
6	14 only	-	-	-	YES

Source: Author's summary (2017).

III. FINDINGS

1. Sixteen days (1^{st},2^{nd},3^{rd},4^{th},6^{th},7^{th},8^{th},11^{th},18^{th},19^{th},21^{st},23^{rd},24^{th},26^{th},27^{th} and 31^{st}) received enough sunshine of three hours each to have been able to cook lunch and dinner of hard beans (as in Table 5).
2. Two days (5^{th} and 28^{th}) of enough sunshine for 3hours to cook lunch and just enough two hours for dinner,
3. On the 25^{th} August the sunshine received collectively for the day from morning to evening was only able to cook rice,
4. The sunshine received within four days (10^{th}, 15th, 22nd, and 29^{th}) in this precipitated month was only able to cook rice of two hours each day in the morning hours for lunch.
5. Another five days (10^{th}, 15^{th}, 22^{nd}, and 29^{th}) of sunshine could only cook dinner of hard beans.

6. A long wait of thermal collection yielded only two effective hours of sunshine on the 14th just to cook rice for dinner.

The Table also revealed that at the peak of raining season direct solar thermal used as a cooking fuel needs only three hours in the morning effective periods to cook lunch and dinner if stack at the same time. Within this period only six days were recorded cooking dinner without lunch due to the early morning hindrances of clouds and rainfall but cooking started from the morning hours to evening.

IV. CONCLUSION

The climatic condition of Kaduna city revealed two stages weather hindrance: the harmattan period and the raining season, the former have high sunshine and solar radiation at the peak hours of effective cooking (10:00am to 4:00pm according to (SCC 2015), enough to cook two meals a day from the experiment performed. The rainy season poses a higher threat, however the experiment conducted proved that at the peak of bad weather pocket of sunshine and solar radiation can give enough fuel to cook.

It is therefore no longer a threat for using direct concentrated solar thermal as a cooking fuel everyday in Kaduna dwellings

V. REFERENCES

[1] Ali, I. N., & Richard G. H. (2013). Northern Nigeria's dependence on fuel wood: Insights from nationwide cooking fuel distribution data. International Journal of Humanities and Social Science, 3(17).

[2] Amod, K. P., Kirk, R. S., Asheena, K., Amar, D., & Michael, N. (2005). Case–control study of indoor cooking smoke exposure and cataract in Nepal and India. International Journal of Epidemiology, 34(3), pg 702–708. Retrieved on 01/05/2013 from https://doi.org/10.1093/ije/dyi015

[3] Baiyegunhi, L. J. S., & Hassan, M. B. (2014). Rural household fuel energy transition: Evidence from Giwa LGA Kaduna State, Nigeria energy for sustainable development, 20, pg 30–35. Retrieved on from http://www.sciencedirect.com/science/article/pii/S0973082614000155

[4] Boumann, E. S. (2014). The effectiveness of practical instructional guide for building climatology in department of architecture Kaduna polytechnic. Journal of Environ-Tech, College of Environmental Studies, Kaduna Polytechnic, Kaduna. 1(5), pg 104. Published by Journal Committee of College of Environmental Studies, Kaduna Polytechnic, Kaduna. ISSN:2141-9698.

[5] Carmel, L. (2013). The 3 biggest obstacles to a solar energy boom. Retrieved on 25/07/2014 from http://theweek.com/articles/463150/3-biggest-obstacles-solar-energy-boom

[6] Carmel, L. (2015). Cooking when is the best time? Solar cooker at Cantinawest. 2008-2015 Solar. Retrieved on 25/07/2014 from http://www.solarcooker-at-cantinawest.com/solarcooking-when.html

[7] Danowitz, A. (2010). Solar thermal vs. photovoltaic. Submitted as coursework for Physics 240, Stanford University, Fall 2010. Retrieved on 17/08/2014 from http://large.stanford.edu/courses/2010/ph240/danowitz2

[8] Dino, G. (2012). Solar energy facts – concentrated solar power (CSP) Vs photovoltaic panels (PV). Renewable Green Energy Power Articles, information and opinions on renewable energy technology and green power, January 13th 2012. Retrievedon 15/07/2014 from http://www.renewablegreenenergypower.com/solar-energy-facts-concentrated-solar-power-csp-vs-photovoltaic-pv-panels/

[9] Kalogirou, S. A. (2004). Solar thermal collectors and applications. Progress in Energy and Combustion. Solar Cookers International (SCI) 30: 231–295.

[10] Omonijo, A. (2014). Rainfall amount and number of rain days in Kaduna, Northern Nigeria–implication on crop production. International Conference on Agricultural, Ecological and Medical Sciences (AEMS-2014), London, United Kingdom. July 3-4, 2014.

[11] Sheyin, F. T. (2005). Solar Cooking in Nigeria. RIO 5 - World Climate & Energy Event, 15-17 February 2005, Rio de Janeiro, Brazil. Centre for Energy Research and Training, Ahmadu Bello University, Zaria, Nigeria

[12] Solar Cooker at Cantinawest [SCC] (2015). Solar cooking: When is the best time? Retrieved on 15/05/2016 from http://www.solarcooker-at-cantinawest.com/solarcooking-when.html

[13] Zhang, X., Shen, J., Hong, Z., Wang, L., & Yang, T. (2015). A Review of Building Integrated Solar Thermal (Bist) Technologies and their Applications. Journal of Fundam Renewable Energy Application, 5(182).

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