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Design, Construction And Performance Evaluation Of A Solar Agricultural Drying Tent

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ABSTRACT

The solar drying tent described in this paper can be used for drying various agricultural produce under hygienic conditions. The solar collector/drying platform with area of 29.6ft^2 (8ftx3.7ft) has black clothing material to absorb solar radiation on which agricultural produce to be dried is spread. The black clothing material is line with rubber mesh Undernet it. Two long sides(length) of the solar collector/drying platform are covered totally with black clothing material while the remaining two sides(breadth) are covered half-way up with black material and the remaining half-way up with rubber mesh. The solar collector/drying platform are covered with transparent polythene sheet to allowing radiation from sun to fall on the collector. The result shows temperature above 50^{0}C inside the drying tent and temperature greater than that of the sun drying surface with an average of 6.25^{0}C. The moisture content of okra was reduced from 86.05% to 3.43% in 23hrs of effective drying.

KEY WORDS

Absorber, Okra, Moisture content, Temperature, Relative Humidity

INTRODUCTION

The application of solar energy for the prevention of post harvest crop losses is a common practice among Nigerian farmers. In spite of the age-long experience in the use of sun-drying, current post-harvest crop losses is still as high as 30-50% for fruits, vegetables and some tuber crops. Traditional method of drying in Nigeria is to spread the products on the ground in the open for exposure to the sun. As a country situated within 4-14 latitude north of the equator, Nigeria is of course, abundantly blessed with all year round solar radiation (Taiwo T. A. 1985). Sun-drying method may be an efficient and cheap process but has disadvantages such as contamination by dirt, insects and bacteria and loss due to wetting by rain squalls and animals interference, these makes the produce unhygienic and are usually accepted as an inherent part of the processing method. In order to protect the products from above mentioned disadvantages and also to accelerate the drying time, different types of solar dryer can be use (Fohr and Figueredo 1987).

The cost of construction is an important consideration in designing a solar dryer. No matter how well a solar system operates, it will not gain widespread use unless it presents an economically feasible alternative to other available energy sources, other dryers and other drying method, (Azad E. 2008). This work will therefore concentrated on a low-cost solar agricultural drying tent that can use to dry various agricultural produce under hygienic condition and can be built from locally available materials and by locally available artisans.

Drying Overview

Drying preserves food by removing enough moisture from food to prevent decay and spoilage. Water content of properly dried food varies from 4 to 25 percent depending on the food (Eze J. I and Agbo K. E 2011). Successful drying depends on:

- Enough heat to draw out moisture, without cooking the food
- Dry air to absorb the released moisture; and
- Adequate air circulation to carry off the moisture.

When drying foods, the key is to remove moisture as quick as possible at a temperature that does not seriously affect the flavour, texture and colour of the food. If the temperature is too low in the beginning, microorganisms may grow before the food is adequately dried. If the temperature is too high and the humidity is too low, the food may harden on the surface. This makes it more difficult for moisture to escape and the food do not dry properly. Although drying is a relatively simple method of food preservation, the procedure is not exact (David E. and Whitfield V. 2000)

Many different solar drying techniques exist in drying of agricultural produce, such as traditional open sun drying, natural convection solar drying and forced convection solar drying. This dryer combined the principle open sun drying and natural convection solar drying.

MATERIALS AND METHOD

The materials that were used include; 2, 1.5, 0.5 inch round pipes, 5/8 inch square pipes, Transparent Polythene sheet, Rubber wire mesh, Black clothing material, Okra, thermo-hygrometer, Moisture metre and pegs.

Descriptions of the Dryer

The solar tent dryer considered in this work is an improvement on the common sun drying method. Here the product is spread on a black clothing material (absorber) which is elevated 2.5ft from the ground and has a roof covered with thick transparent polythene sheet to form the drying chamber. Solar radiation is not incident directly on the produce with the interception of the sun rays by the transparent roofing sheet. The black clothing material and the roofing sheeting also protect the drying chamber and its content from direct exposure to external influence. Further description of the various parts of the drying tent is discussed below;

Drying Chamber/Absorber

The drying chamber has a drying platform with area of 29.6ft^2 (8ft x 3.7ft) and a height of 1ft; it's lined at it base with rubber mesh and black clothing material that act as absorber. The two short sides (breadths) are totally covered (1ft up) with the black clothe while the remaining two long sides (lengths) are covered half-way up(1/2ft up) with the black clothing and the remaining half-way up with rubber mesh. The black clothing material was chosen since a black surface is expected to absorb more heat and also the material will allow excess moisture to drain. Vaporized moisture will escape though the space created by the half netted long sides of the chamber.

Roofing

This is a metal frame work covered with transparent polythene sheet to protect the absorber/drying chamber, thereby limiting the direct interaction of the produce being dried with its environment. The gable roof has an area 2ft^2 (1/2 x 4ft x 1ft) and length of 9ft, covered with a transparent material. It also prevent direct incident of solar radiation on the dried produce and retards heat absorbed by the absorber from wasting away before heating up the produce and vaporizing its moisture (i.e. forming a confinement for heated air). It is placed 1ft above the absorber.

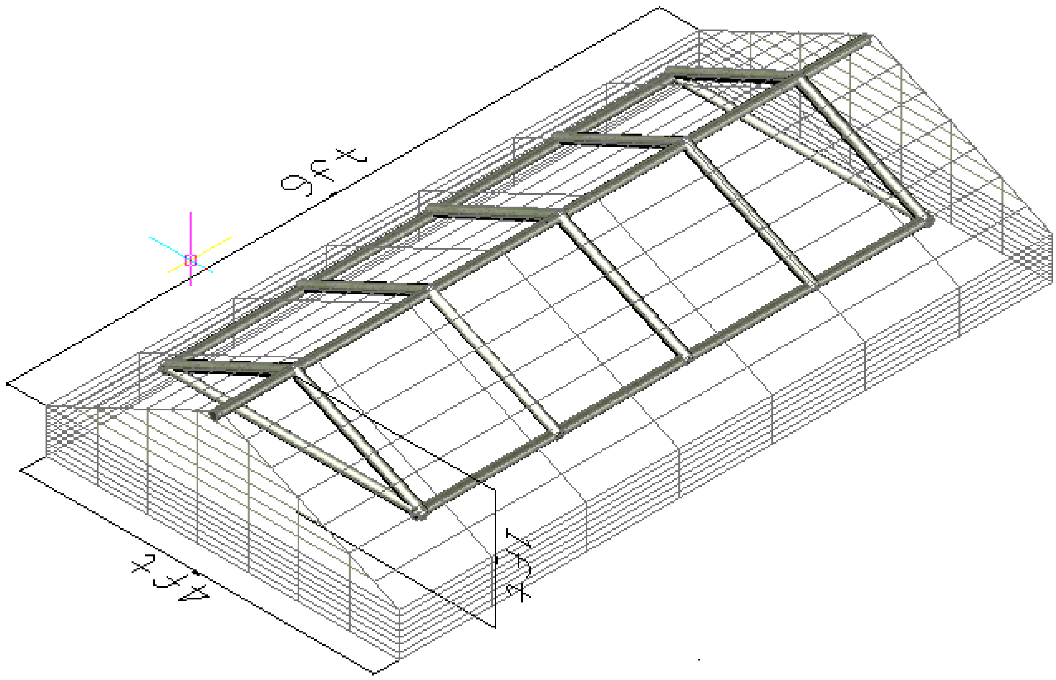

Fig 1: The drying tent roof frame work with transparent roofing sheet

Common materials that can be use as cover for the roof are flexi glass, fibreglass, reinforced polyester, thin plastic films and plastics. These materials must not be coloured and must be transparent.

Body Frame work

The dryer has six(6) detachable stands 2.5ft high, a rectangular cubic frame that has it bas as the drying platform with an area of 29.6ft^2 (8ft x 3.7ft) and height of 1ft, serving as the drying chamber/absorber and a the roof sitting on it.

All materials used in construction of this drying tent have alternative material(s) that can be use depending on which material is readily available and particular to an area.

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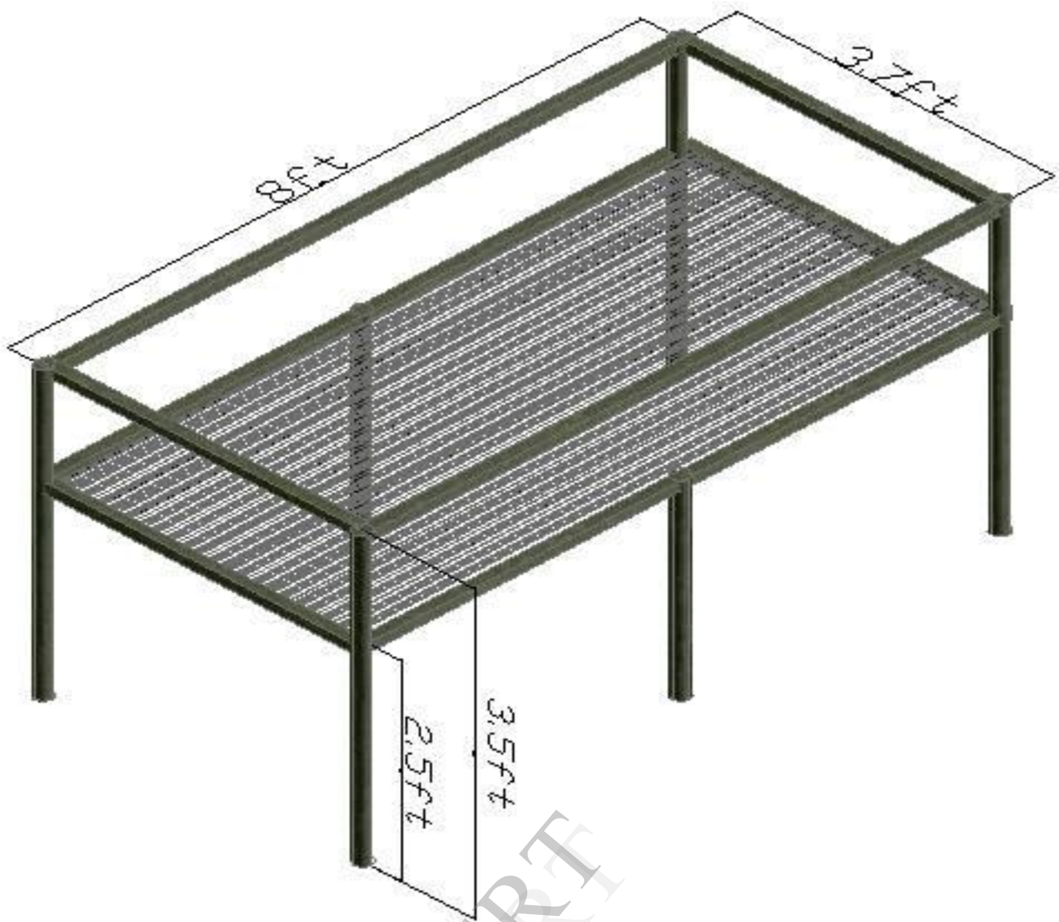

Fig 2: The drying tent body frame work

After the design and fabrication had been completed, two tests will be carried out to evaluate it performance;

Test 1: No-Load Condition;

- The drying tent was setup and placed in an open space where no structure cast shadow on it, the and relative humidity inside the tent and that of the ambient was measured simultaneously at interval of 1hour from 8am to 6pm for five days within a week using thermo-hygrometer

Test 2: Loaded Condition;

- Fresh okra was purchased, washed and sliced with thickness of 15mm
- Sample was taken from the fresh okra for moisture analysis to get the initial moisture content using moisture meter.
- The sliced okra was divided into two parts; one part was dried using the drying tent and the other using open sun drying method which serves as control. Both dryings were done simultaneously
- Sample was taken daily for moisture analysis (moisture lost) from both drying method until the okra was properly dried

- The Temperature and relative humidity inside the dying tent and that of the ambient was measured simultaneously at interval 3hrs from 10am to pm within the drying period of the okra
- A confirmatory test was conducted using the same procedure to cross-check the first result
- Sensory Analysis was carried out by a panel of nine (9) assessors.

TESTING

The testing of the solar dryer was done in the months of June and July 2012. The solar drying tent was placed outside to it can receive sun ray where no shadow can be cast on it by any structure. The test both for 'no-load condition' and 'loaded condition' was carried out according to the procedure in methodology above. Sensory evaluation for colour, flavour, taste and aroma was carried out by a panel of 9 assessors using a multiple comparison difference analysis (Larmond, 1977) on a hedonic scale. The sensory evaluation results were subjected to statistical analysis using Duncan's multiple procedure to determine which sample differed significantly to another.

RESULTS

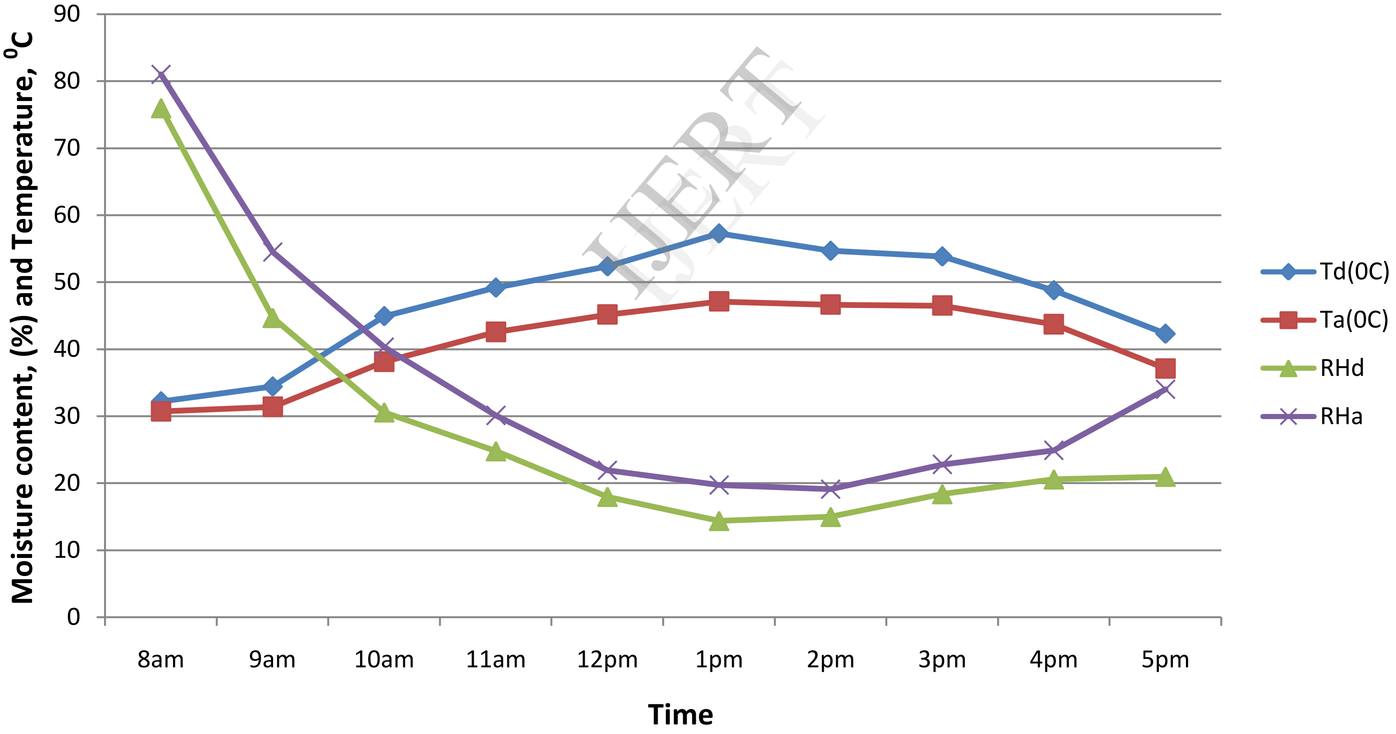

Fig 3: Graph showing average variation of Temperature and Relative Humidity with Time for No-Load Test conducted from 4th – 8th June 2012

Indicators: T_d = Temperature in the drying tent, T_a = Temperature on the sun-drying surface, RH_d = Relative Humidity in the drying tent for, RH_a = Relative Humidity on the sun-drying surface

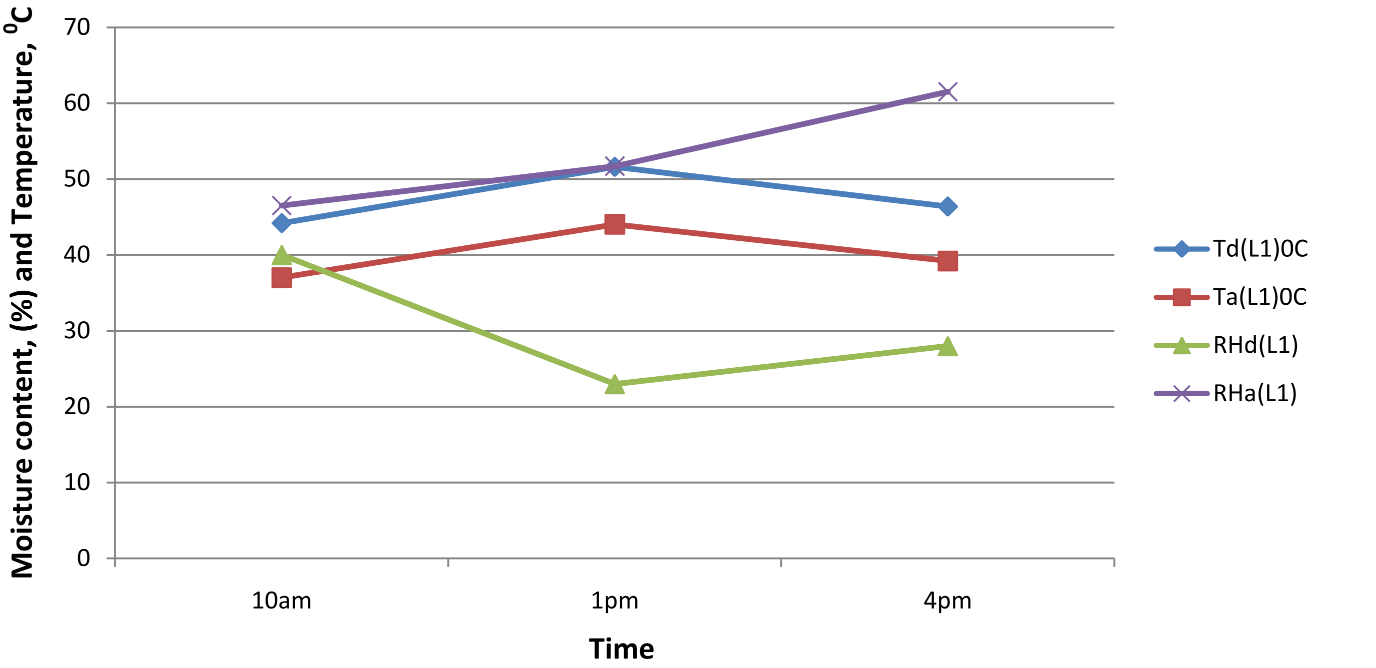

Fig4: Average Variation of Temperature and relative humidity with Time for Loaded Test (4th - 6th July)

Indicators: T_d (L1) =Temperature in the drying tent, T_a (L1) = Temperature on the sun-drying surface, RH_d (L1) = Relative Humidity in the drying tent, RH_a (L1) = Relative Humidity on the sun-drying surface

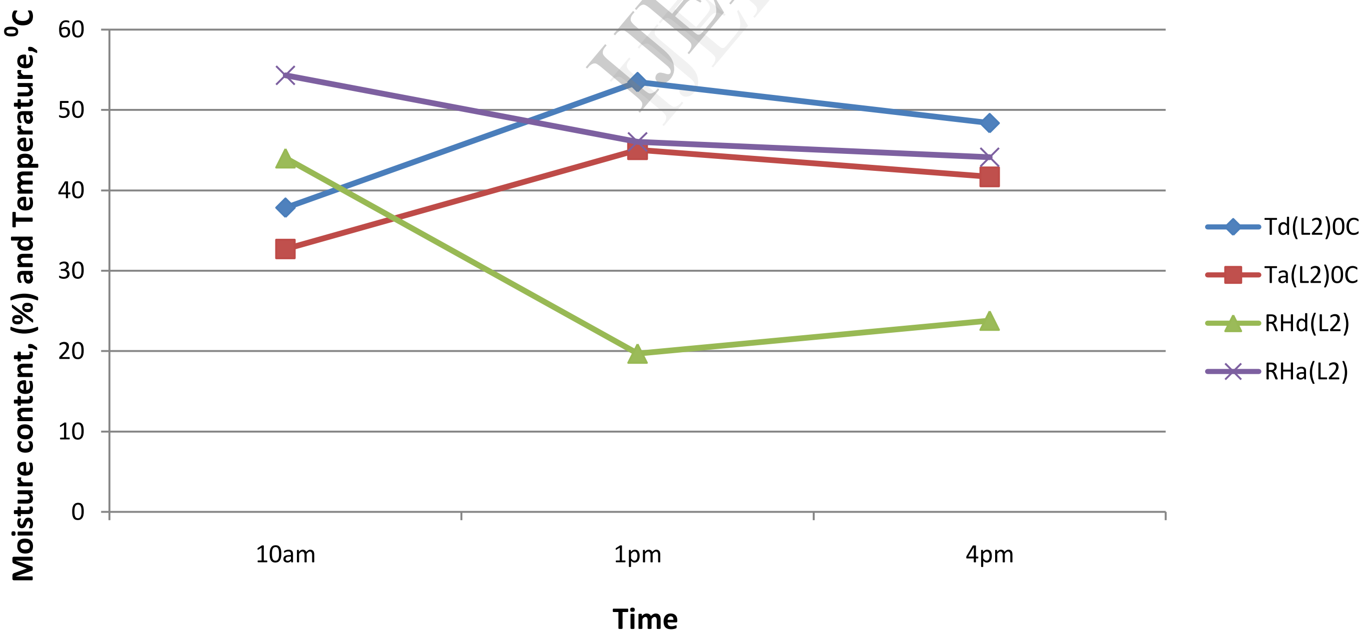

Fig 5: Average Variation of Temperature and relative humidity with Time for Confirmatory Loaded Test (9th -11th July)

Indicators: T_d (L2) = Temperature in the drying tent, T_a (L2) = Temperature on the sun-drying surface, RH_d (L2) = Relative Humidity in the drying tent, RH_a (L2) Relative Humidity on the sun-drying surface

Table 1: Drying Rate (Loaded Test) 4th - 6th July

Crop	Method of drying	Thickness of slice (mm)	Total drying Time, TDT (hr)	Effective drying time, EDT (hr)	Moisture content (MC) wet basis (%)			
					Initial	At 8hrs EDT	At 15hrs EDT	At 23hrs EDT
Okra	Solar tent	15	56	23	86.05	56.88	9.78	3.43
	Open Sun	15	56	23	86..05	68.06	38.88	30.20

Table 2: Draying Rate (Confirmatory Loaded Test) 9th -11th July

Crop	Method of drying	Thickness of slice (mm)	Total drying Time, TDT (hr)	Effective drying time, EDT (hr)	Moisture content (MC) wet basis (%)			
					Initial	At 6hrs EDT	At 10hrs EDT	At 30hrs EDT
Okra	Solar tent	15	50	30	88.91	65.11	11.21	2.50
	Open Sun	15	50	30	88.91	71.92	49.68	9.31

For table 1&2 EDT = Effective drying time, TDT = Total drying time

Table 3: Sensory Attributes of Dried Okra

Characteristic	Sun drying	Solar tent drying	Sun drying (confirmatory)	Solar tent drying (confirmatory)
Colour	5.56	7.55	4.56	7.62
Aroma	5.11	6.92	5.33	7.10
Taste	4.44	7.56	3.78	7.22
Texture Acceptability	4.72	7.98	3.57	7.87
Overall Acceptability	4.96	7.50	4.31	7.45

RESULT DISCUSSION

Testing at no-load condition: The result at no-load indicated that a maximum temperature of 57.2^{0}C was achieved in the drying tent when the temperature on the sun-drying surface was 47^{0}C. Fig 3 shows that the temperature inside the drying tent is greater than that of the sun drying surface by an average of 6.1^{0}C, it also shows that relative humidity inside the drying tent is lower than that of the sun drying surface with an average of 6point. With the knowledge that higher temperature and lower humidity is favours drying, this result indicated that there will be a better performance by the drying tent in terms of drying time compared to sun drying.

Testing at Loaded condition: experiments were carried out to investigate the performance of the solar tent with reference to sun-drying. Two tests were conducted with the second test serving as a confirmatory test. Fig 4 and 5 confirm the result of the test at no-load condition (fig 3) with the temperature inside the drying chamber of the solar tent higher than that on the sun-drying surface by an average of 6.9^{0}C and Relative humidity lower by an average of 20points. Fig 4 also shows that the relative humidity inside the drying tent did not change sharply even when there was shape changes in weather condition which is a usual phenomenon during wet season. The ability of the tent to maintaining a relatively constant drying condition and allow for the occasional rain drizzle without the need to remove the produce from the dryer makes it good for drying especially during the wet season when there is usually sharp change weather condition alternating between low and high relative humidity and temperature within a small period of time by and occasional rain drizzles. Table 1 and 2 shows that the okra dried faster in the solar tent compared to sun drying. The total drying time represent the duration of drying the okra (day and night time) while the effective drying time represent the day time only.

Final Moisture Content: At the same drying conditions and time, table 1 and 2 shows that the okra dried from initial moisture contents of 86.05% to 3.43% in the tent and to 30.20% on the sun drying surface and from initial moisture content of 88.91% to 2.50% in the tent and to 9.31on the sun drying surface for the first and confirmatory tests respectively.

Sensory Analysis: Table 3 showed the mean values for multiple comparison analysis for selected quality attributes of sun-dried and solar tent dried okra samples for the two tests. The panel preferred the solar-tent dried okra for the first and the confirmatory test to the sun-dried one as there was significance difference in colour, aroma, taste, texture-acceptability and overall acceptability.

This preference is attributed to the fact that the solar radiation does not incident directly on the crop during drying and the interaction of the crop with its environment is relatively minimal thereby reducing contamination level which impact on the quality of the solar tent dried okra. These factors can also be said to have positive effect on the colour, aroma, texture and inevitably the taste. These results indicated better performance (improvement on drying time and the quality of dried produce) by the drying tent relative to sun drying with. The size of the tent depends on the capacity of the farmer in terms availability of space, quantity to be dried, and financial capability.

CONCLUSION

A solar drying tent was constructed and tested with the aim of using it instead of sun-drying of crops on the bear floor especially along the highways by farmers and processors alike both at small, medium and large scale of various agricultural crops in Nigerian. The result shows temperature above 55^0C inside the drying tent. The temperature inside the drying chamber of the solar tent was greater than that of the sun drying surface with an average of 6.25^0C. The moisture content of okra was reduced from 86.05% to 3.43% in 23hrs of effective drying time using the tent.

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