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# Comparative Performance Evaluation of PVT Assisted Dryer And Conventional Solar Thermal Dryer In Drying of Tomatoes (*Lycopersicon Esculentum*)

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***ABSTRACT***

Drying is an essential post-harvest preservation method for agricultural produce. Since drying is an energy absorbing process, farmers need to have access to effective dying techniques in order to maintain the quality of the products and maximize their profit. Hence, A Solar hybrid (PV/T) assisted dryer was designed, constructed and evaluated for drying of Tomatoes (*Lycopersicon Esculentum*). The load test drying efficiency of Solar Hybrid (PV/T) dryer was compared to Conventional Solar Thermal Dryer. The daily average moisture content reduction of tomatoes was 0.47g±0.169 while Solar thermal showed average reduction of 0.437g±0.188 for 35 and 37 hours respectively. The result of- t-test revealed there was no significant difference in the daily average drying rate between the hybrid (PV/T) and Solar thermal dryer. The results from the three models indicated moisture content reduction on daily basis shows that polynomial model has the highest ($R^2$=0.9937, $R^2$=0.9975) value and this implies that the average daily moisture content reduction of tomatoes for hybrid (PV/T) and solar thermal dryer were best described by polynomial model. The result of the proximate analysis conducted for the dried tomatoes sample using (PV/T) hybrid dryer and Solar thermal dryer indicated that ash content (5.3%), moisture content (13.31%), lipid (0.87), protein (8.87%), fiber (5.48%) `was significantly lower in sample dried with solar thermal dryer, while the lipid content (0.64%) and available carbohydrates (62.3%) are lower in tomato dried with Solar thermal dryer. The mycology test conducted for the fresh and dried tomatoes samples revealed the presence of the following fungi; *S. cireviceae, S. Pombe, F. oxyspurum and F. solani* with highest frequency of occurrence of *S. solani* (28%) and *S. Pombe* with lowest (3.96%) respectively. The collection efficiency of the dryer on drying of 4kg tomato sample was 42.49 %, pickup efficiency 36.89% and System efficiency 5.63%. The result obtained showed that PVT hybrid dryer is better option for drying compared to solar thermal dryer.

**Key words**: Drying, Hybrid dryer, PV/T, Solar thermal, Moisture content, Tomato.

## 1.0 INTRODUCTION

Drying involves the extraction of moisture from the product by heating and the passage of air mass around it to carry away the released vapor. Under ambient conditions, these processes continue until the vapor pressure of the moisture held in the product equals to that contained in the atmosphere. Thus, the rate of moisture absorption from the product to the environment and absorption from the environment are in equilibrium, and the crop moisture content at this condition is known as the equilibrium moisture content. Under ambient conditions, the drying process is slow, and in environments of high relative humidity (Dincer, 2020).

Drying technology has vast applications in many branches of industrial production. It is irreplaceable in the chemical and petrochemical industry, in medicine, food production, fruit, and vegetable drying technology as well as in the processing of grain, lumber and many other organic and nonorganic materials. In today's world of rapidly advancing technology, drying is an essential component of industrial process engineering (Lelise *et al.,* (2021); Qiu, 2019)

Drying is one of the significant aspects of agricultural production and manufacturing. Almost all materials need drying before they can be marketed and processed (Afdhal *et al*., 2020)
Drying is employed in the food industry to preserve and extend the shelf-lives of food since, at very low water content, microbial spoilage and many chemical reactions are slowed down or even halted. Moreover, drying decreases the product volume and its weight, which benefits handling and transportation costs, (Qiu, 2019). There is a growing market of dried food ingredients with high added value, such as thickeners, emulsifiers, flavoring, and pigments, which requires increasing drying capacity and further optimization of the quality of the final dried products (Qiu, 2019).

**1.1 Solar Hybrid PVT Drying**
A hybrid (PVT) collector is basically a combination of a flat plate thermal collector and a PV solar panel. The PV panels harness only a fraction of the incoming solar radiation as most of the absorbed solar radiation is dumped to the PV panel as waste heat and thus resulting in a considerable increase in the temperature of the PV panel leading to dramatic decrease in the cell's efficiency. The conversion efficiency of the available commercial solar photovoltaic panels ranges between 5 – 20%, thereby causing heat buildup, thus affecting their performances. Air being a medium for cooling, is one of the options for cooling the solar panel through heat removal and consequent efficiency enhancement (Hussein *et al.,* 2017).

**The PV/T assisted dryer**.

**2. 0 MATERIALS AND METHODS**
**2.1 Materials selection**
The various factors considered in selection of the materials for the fabrication of the dryer are: (i) cost of the fabrication (ii) mechanical properties of the materials (iii) corrosion resistance and (iv) ease of fabrication and service requirement.

**2. Materials and Methods**
The materials used for the solar dryer construction were relatively cheap and locally available in local market. The solar assisted dryer consists of solar collector, drying chamber with rack and solar PV panel. The solar collector consists of an absorber, a glass cover, a PVT collector black plate and an insulator. The single layer of typical glass covers the top of the collector, the bottom and edges of the collector are all insulated with saw dust material to minimize heat losses.

**2.1.1 Tomato Samples**
The tomato samples used for the drying were gotten from popular vegetables market in Sokoto Kara market. The sample is popularly grown withing the Sokoto fadama area.


Sorting of Tomato


Dried Tomato

### 2.1.2 Instruments for the Experiments

The measuring instrument used for the experiments and their model numbers are listed in table 1 bellow.

**Table 1: List of Materials and Instruments**

| S/NO | ITEMS | SPECIFICATION | QUANTITY |
|---|---|---|---|
| 1 | Digital Pyrometer | Model No (080692) | 1 |
| 2 | Digital Anemometer | Model No (407113) | 1 |
| 3 | Digital Weighting Balance Model | Model No (test 0605-HI) | 1 |
| 4 | Digital Multimeter | Model (UT51) | 1 |
| 5 | Digital Thermometer Module | Model no (305) | 2 |
| 6 | Thermocouple Wires | | Lots |

## 2.2 Methods

### 2.2.1 Sample Preparation

The samples used were purchased at Sokoto Kara market, Sokoto North Sokoto state Nigeria, the samples were prepared in four phases, viz: sorting, washing, slicing and sample specification.

The samples were sorted by visual inspection where physically damaged, unripe and overripe samples were removed and discarded. The selected samples were thoroughly washed with copious amount of tap water. The samples were cut in halves.

### 2.2.2 Description of the drying method

The prepared samples were divided into four portions of 1 kg each, which were then placed in four drying racks respectively. The racks were then placed in the PV-assisted dryer and conventional thermal dryer. The drying was started at 9 am t, and weight of the samples on each rack were taken at an hourly basis over a period of 7 hours.

### 2.2.2 Proximate Analysis

#### 2.2.2.1 Determination of Moisture Content

The AOAC, (2023) method was used. Empty clean dishes were dried in an oven at 105$^0$C for an hour and cooled in desiccator. Sample (2g) was weighed into each dish and heated in an oven at 105$^0$ C for 24h. The dishes were removed from the oven, cooled in the desiccator and weighed. The process was repeated several times until reaching weigh constancy. Moisture content was then calculated as percentage water loss using equation 1.

$$Moisture\ content\ (\%) = \frac{w_1 - w_f}{w_i} \text{ x } 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(1)$$

$w_i$ = Initial weight of the sample before drying

$w_f$ = Final weigh of sample after drying

#### 2.2.2.2 Ash content

Ash content was determined using association of analytical chemistry (AOAC, 2023) method. Dried sample (2g) was weighed into a pre-heated and cooled crucible and incinerated in a muffle furnace (Lenton furnace England) at 550$^0$C for six hours. The ashes were then cooled in desiccator and weighed. Ash content was then calculated using equation 2.

$$Ash\ (\%) = \frac{weight\ of\ ash}{Weight\ of\ dired\ sample} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

#### 2.2.2.3 Crude lipid determination

The soxhlet method (AOAC, 2023) was adopted for Crude lipid determination. Dried sample (2g) was used into porous thimble, to which its mouth was plugged with cotton. The thimble was placed in an extraction chamber, which was suspended above receiving flask (previously weight) containing petroleum ether (p. 406$^0$C) and below a condenser. The flask was heated on heating mantle and the oil extracted. The extraction lasted for eight hours after which the thimble was removed the ether. The flask containing the crude lipid was then disconnected, cleaned with dry cloth and placed in an ovum at 100$^0$C for 30 min. After the heating, the flask was cooled in descriptor and weighed. The percentage crude lipid content was calculated using equation 3.

$$Crude\ lipid = \frac{weight\ of\ oil\ extracted}{Weight\ of\ sample} \text{ x } 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

#### 2.2.2.4 Determination of Crude Fibre

This was done using AOAC, (2023) method. The principle of the method is based on loss of crude fibre when ignited after being digested with acid and base.

The following reagents were used for the determination of crude fibre;

The powdered sample (2g) was defatted as described in 2.7.3. The defatted sample was then transferred into a 600 cm$^3$ beaker and 200cm$^3$ of boiling 1.25% $H_2SO_4$ added. The content was boiled for 30 minutes on hot plate. After boiling, the mixture was cooled and filtered through a Whatman No. 1 filter paper and the residue washed with three 50 cm$^3$ portion of boiling water. The drained residue was then quantitatively returned to the original beaker and 200cm$^3$ of boiling 1.25% NaOH was added. The content was then boiled for 30 min., filtered as above, washed with 25cm$^3$ boiling 1.25% $H_2SO_4$ and three 50 cm$^3$ portion of boiling water. Finally, the residue was drained and washed with 25cm$^3$ alcohol. The filter paper water containing the residue was then dried in an oven at 130$^0$C for 2h, cooled in desiccator and the content quantitatively put in a pre-weighed crucible and reweighed. The crucible was then ignited at 550$^0$C for 2h cooled in the desiccator and weighed. Crude fibre content was calculated using equation 4

$$Crude\ fibre\ (\%) = \frac{loss\ in\ weight\ on\ ignition}{Weight\ of\ sample} \text{ x } 100 \ldots\ldots\ldots\ldots (4)$$

#### 2.2.2.5 Determination of Crude Protein

The crude protein of the sample was determined using micro-Kjeldahl method of AOAC, (2023).
Dried sample (2g) was weighed into Kjeldahl digestion flask and 0.5g of catalyst mixture ($Na_2SO_4$ $CuSO_4$ and selenium oxide in a ratio 10:5:1) was added followed by addition of 10cm$^3$ of concentrated tetraoxosulphate (VI) acid. The content was then heated in Kjeldahl digestion unit the digest become clear (approximately 2h). After the digestion had been complete, the flask was cooled, diluted with 10cm$^3$ distilled water and filtered with a Whatman No. 1 filter paper into a 100cm$^3$ volume flask of homogenous aliquot solution was pipetted into distilled flask and 20cm$^3$ of 45% NaOH solution was added. The content was diluted to about 200cm$^3$ with distilled water and distilled using micro-Kjeldahl distillation apparatus. The distillate was received into a receiving flask containing 10cm$^3$ boric acid indicator solution. After the distillation, the distillate was titrated with standardized 0.01M HCl to the end point. Blank determination using all the reagents in the same quantities (but without the sample) was carried out as described above. The process was carried out in triplicate and the crude protein (CP) calculated using equation 5.

$$CP\ (\%) = \frac{(a-b)x\ 0.01M\ HClx\ 14xc}{dxe} \text{ x } 6.25\ x\ 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

#### 2.2.2.6 Determination of Available Carbohydrate

The nitrogen –free extractive (NFE) which is referred to as soluble carbohydrate was determined by obtaining the sum of ash, crude fibre, crude fat and crude protein and subtract it from 100, as shown in equation 6.

N.F.E =100 – (% ash +% crude fibre + crude f + crude protein)………………….(6)

### 2.2.3 Isolation and identification of Bacteria and Fungi

#### 2.2.3.1 Bactria identification

A serial dilution of each sample was made by taking 1ml of the sample using a sterile syringe needle and transfer onto 9ml of sterile water in a test tube was drawn and transferred onto the second test tube also containing 9ml of distilled water and mixed 1ml was also transferred from the second test tube onto the third test tube of 9ml of distilled water. This procedure was carried out up to the $6^{th}$ test tube. Then 1ml was drawn from each of the last test tube (dilutions) of each sample and inculcated into nutrient agar using spread plate method of inoculation. These were then incubated at $37^0$c for 24hours.

The total aerobic plate count was carried out on all the twelve plates. The different distinct colonies from the plates (cultures) were picked and gram stained. Then further biochemical analyses were carried out for the identification of the species.

**2.2.3.2 Identification of Fungal Isolates**

Small portion of the pure culture was placed or the drop of lectol phenol blue and the greese slid usually innovation uses and was covered with cover slip. The slid was mounted on a light microscope state and examined using x 4 power objectives and x 10 respectively.

**Procedure**

Media preparation: the media was prepared according to the manufacture's instruction 39g of media was dissolved in 1000mls of distilled water, 1g of antibiotic was added to the mixture to inhibit the growth of bacteria. Cotton wool was used to plug the mouth of the flask and fool paper was used to cover the flask, the mixture was heated to dissolved and aticlued at 121°c for 15min

1g of each of the sample was homogenized in 9ml of sterile distilled water. The homogenate was used as stock solution of each sample. Further serial dilution of the resultant homogenates where made to Fourth ($X10^{-4}$) divalent. 1ml of each dilution was inoculated on sterik potato dextrose ager (PDA) in a petridegh using poor plate method (Fawole and Oso, 2019) The inoculated plates was incubated at room temperature (27°c) for 3-7 days the number of individual fungi poor plat was recorded as well as the percentage frequency of each isolate

**2.2.4: Determination of Cations and Heavy Metals**

The sample is been run using MPAES machine of model 4200 at Energy Research Centre Sokoto, Usmanu Danfodiyo University Sokoto

**Procedure for Digestion Method**

About 2g of the sample was mixed with 4 $cm^3$ of n H M C acid, 2 $cm^3$ of perchloric acid and heated to digest for about 5-10 minutes, it was allowed to cool to room temperature and filted with filter paper, the filtrate was then diluted with distilled water and make up to 50 $cm^3$. After which the sample was ran by using MPAES Machine.

## 3. RESULTS AND DISCUSSION

### 3.1 Result of Daily moisture content reduction of Tomato using PV/T and Solar Thermal dryers

Figure 1 shows the result of regression analysis on average daily moisture contents of tomatoes drying under hybrid (PVT) dryer using linear, polynomial (quadratic) and exponential regression model. The results from all the three models indicated moisture reduction on daily basis. The result shows linear model $y = -0.2369x + 1.1892$ with $R^2 = 0.9751$, polynomial model $y = 0.0277x^2 - 0.4031x + 1.3831$ with $R^2 = 0.9937$ and exponential model $y = 2.3422e^{-0.648x}$ with $R^2 = 0.9679$. Among the three models, polynomial model has the highest $R^2$ and this implies that average daily moisture reduction of tomatoes under PVT dryer is best describe by polynomial model. The result agrees with that of (Wengang *et al*., 2020).

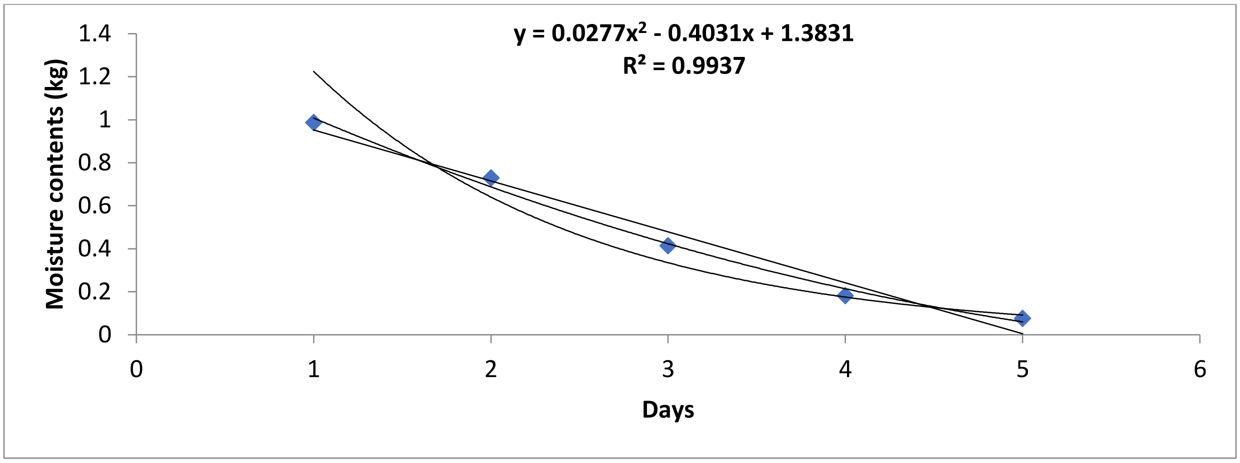


**Figure 1: Results of Regression Analyses for Linear, Quadratic and Exponential Models for PVT Daily Average Drying of Tomatoes**

Figure 2 shows the result of regression analysis on average daily moisture contents of tomatoes drying under solar thermal dryer using linear, polynomial (quadratic) and exponential regression model. The results from all the three models indicated moisture reduction on daily basis. The result shows linear model y=-0.2516x+1.1914with $R^2$=0.8992, polynomial model y=0.0703$x^2$-0.6734x+1.6836with $R^2$=0.9975 and exponential model y=2.4132$e^{-0.721x}$with $R^2$ = 0.9964. Among the three models, polynomial model has the highest $R^2$ and this implies that average daily moisture reduction of tomatoes under Solar thermal dryer is best describe by polynomial model which agrees with (Mukul *et al.*, 2023).

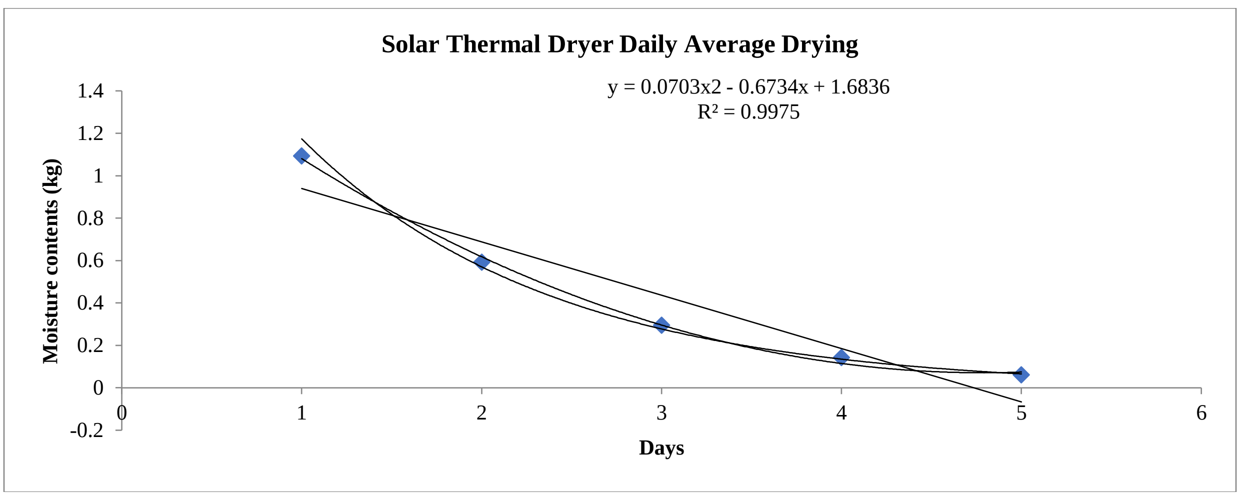


**Figure 2: Results of Regression Analyses for Linear, Quadratic and Exponential Models for Solar Thermal Dryer Daily Average Drying of Tomatoes**

### 3.2 Result of Comparative Analysis

Table 2 shows that comparative analysis of hybrid (PVT)dryer and Solar Thermal dryer on tomatoes drying using t-test. The results were that (PVT) dryer has daily average moisture reduction of 0.47g with standard error 0.169 while Solar Thermal has daily average moisture content of 0.437 with S.E of 0.188. PVT dryer took (35 hrs) while solar thermal dryer took (37 hrs). The result of t-test t=0.165 with P value =0.873 revealed there is no significant difference in the daily average drying capacity between the hybrid PVT and solar thermal dryers.

**Table 2: Comparative Analysis of Tomatoes Moisture Content Reduction Using t-test**

| Dryer | Duration | Mean | S.E | T | p-value |
|---|---|---|---|---|---|
| PVT dryer | 35hrs | 0.479 | 0.169 | 0.165 | 0.873 Not significant |
| ST dryer | 37 hrs | 0.437 | 0.188 | | |

Table 3 shows the result of multiple linear regression model and residual analysis of the performance of the Hybrid (PVT) drying of the tomatoes moisture content reduction with respect to predictors variables as relative humidity, wind speed, inlet temperature, solar radiation. The result of the regression model revealed that the above parameters are very significant in drying. The residual analysis revealed that the optimal performance of the hybrid (PVT) dryer as at when relative humidity is 10%, windspeed 0.8 m/s temperature 42.8$^0$Cchamber Temp 42.2$^0$solar radiation 405 W/m$^{2.}$.

**Table 3: Multiple Regression and Residual Analysis for Performance of hybrid (PVT) dryer**

| Predictors | Coefficient | t-test | p-value | Value of predictors with lesser error |
|---|---|---|---|---|
| Relative Humidity | 0.046 | 0.46 | 0.025$^*$ | 10% |
| Wind speed | 0.0038 | 2.35 | 0.945$^*$ | 0.8 m/s |
| Inlet Temp | 0.0377 | 0.07 | 0.022$^*$ | 42.8$^{oc}$ |
| Chamber Temp. | -0.0168 | -3.24 | 0.003$^*$ | 42.2$^{oc}$ |
| Solar Radiation | 0.0003 | 1.83 | 0.041$^*$ | 405 w/m$^2$ |

Table 4 shows the result of multiple linear regression model and residual analysis of the performance of the Solar Thermal drying of the tomatoes moisture content reduction with respect to predictors variables as relative humidity, wind speed, inlet temperature, solar radiation. The result of the regression model revealed that the above parameters are very significance in drying. The residual analysis revealed that the optimal performance of the solar thermal dryer as at when relative is 10m/s, windspeed 0,9 m/s inlet temperature 45.1$^0$C drying chamber Temp 43.8$^0$c and solar radiation 490 W/m$^2$. The result agrees with (Mukul *et al.,* 2023).

**Table 4: Multiple Linear Regression and Residual Analysis for performance of Solar Thermal dryer.**

| Predictors | Coefficient | t-test | p-value | Value of predictors with lesser error |
|---|---|---|---|---|
| Relative Humidity | 0.0353 | 1.44 | 0.049$^*$ | 10% |
| Wind speed | 0.0381 | 0.57 | 0.575$^*$ | 0.9$^0$C |
| Inlet Temp | 0.0401 | 2.05 | 0.048$^*$ | 45.1$^0$C |
| Chamber Temp. | -0.0577 | -2.76 | 0.009$^*$ | 43.4$^0$C |
| Solar Radiation | 0.00043 | 2.02 | 0.048$^*$ | 490 W/m$^2$ |

### 3.3 Isolation and Identification of Bacteria

From the bacteria table shown in appendix VI, the bacteria isolated from the dried tomatoes sample [PVT, STT, PVTF] Which were dried using the dryer, are *Pseudomonas aeruginosa*, *Aeromoesveronil*, *Micrococcus veronil* and *Corynebacterium xerosis*.and*Pseudomonas aeroruginosa*which has the highest frequency of occurrence 44%, *Aeromoesveronil* is the next with 33% while *Micrococcus veronil* and *Corynebacteria xerosis* has 11% each (Shinkafi *et al*., 2020)

*Pseudomonas aeruginosa* which has constituted the highest frequency of occurrence of bacteria specie is a pathogenic and opportunistic pathogen, strict aerobic (although can grow anaerobically in the presence of nitrate), this causes diseases in both plants and animals. In humans, it causes pneumonia and normally inhibit soil, water and vegetation. No wonder it was found on the tomatoes samples which are fruit gotten from vegetation and also cultivated on the soil this agrees with the results of (Tada *et al*., 2006; Shinkafi *et al.,* 2020).

The presence of these microorganisms after drying, using dryer machine could be an indication that the heat generated by the dryer, may not have been hot enough to eliminate the microorganisms present on the fruits or the contamination could be as a result of handling the sample after drying.

### 3.4 Identification and Isolation of Fungi

This study investigated the fungi associated with dried samples of Tomatoes using the two developed dryers Hybrid (PVT) and Solar Thermal (ST) solar Thermal respectively, the result revealed the presence of some fungi. The fungi isolated were *S.cereviceae, S.pombe, F.oxyspurum* and *F.solani*, the result revelled that *F.solani* has the highest frequency of occurrence with 28 % while *S. pombe* has the lowest occurrence of 3.45.The result in table 5and shows the frequency occurrence of fungi in the two different samples (Karina *et al.,* 2021).

**Table 5: Fungi Frequency Occurrence**

| | Frequencies of Occurrence % |
|---|---|
| ***S. Ceresiqe*** | 26.41 |
| ***S. Pombe*** | 3.96 |
| ***F. Oxysporum*** | 11.32 |
| ***F. Solani*** | 28.30 |

### 3.5 Result of Proximate Analysis

From Table 6, analysis of the result show that there was a significant difference ($p>0.05$) in Ash content of Tomatoes dried at solar thermal dryer and PV/T dryer. Tomatoes dried using PV/T has high Ash content (19.83±0.29) compared to that of solar thermal dryer (14.17±0.29). Similar result was also obtained by Marvis *et al.,* (2018).

Similarly, the moisture content of Tomatoes dried using solar thermal and PV/T dryers show significant difference ($P>0.05$ at $\alpha=0.05$). The moisture content of solar thermal dried Tomatoes was found to be 13.00±0.00and that of PV/T dryer was found to be 12.33±0.29. This shows that PV/T solar dryer is more effective in moisture content removal compared to solar thermal dryer, this also corroborate with the result obtained by (Hassan *et al.,* 2019).

**Table 6: Result of Proximate Analysis of dried Tomatoes using Solar thermal and Hybrid PV/T dryers**

| Parameters | Solar Thermal Dryer | Photovoltaic |
|---|---|---|
| Ash (%) | $14.17\pm0.29^a$ | $19.83\pm0.29^b$ |
| Moisture (%) | $13.00\pm0.00^a$ | $12.33\pm0.29^b$ |
| Crude Fibre (%) | $13.33\pm0.29^a$ | $13.67\pm0.29^a$ |
| Crude Lipid (%) | $0.83\pm0.29^a$ | $1.67\pm0.29^b$ |
| Crude Protein (%) | $21.00\pm0.00^a$ | $20.83\pm0.00^b$ |
| Nitrogen content (%) | $3.83\pm0.00^a$ | $3.33\pm0.00^b$ |
| Available Carbohydrate | $37.67\pm0.29^a$ | $31.67\pm0.00^b$ |

- **Data are mean ± the standard deviation of three replicates measurements**
- **Values within the same rows with different subscript are significantly different at $p<0.05$**

However, the crude fibre of the Tomatoes dried using the two drying methods show no significance difference ($P > 0.05$). This indicates that, solar thermal and PV/T dryers, have no effect on the crude fibre content of Tomatoes.

Again, the crude lipid of the Tomatoes dried using the two drying methods show that, there is significance difference ($p< 0.05$). For solar thermal and PV/T dryers, the crude lipid content was found to be 0.83±0.29 and 1.67±0.29 respectively.

The result of crude protein in solar thermal dried Tomatoes (21.00±0.00) is significantly higher than that of PV/T dryer (20.83±0.00) which could be due to concentrated heat energy in the PV/T dryer. Similar result was also obtained by Marvis *et al.,* (2018).

Analysis of the results of dried Tomatoes using solar thermal and PV/T dryers shows significant difference in Carbohydrate content. The highest carbohydrate content (37.67±0.29) recorded in solar thermal dried Tomatoes is as a result of the highest temperature in the dryer which resulted in high dry matter content in the form of starch.

The result of Nitrogen content of Tomatoes dried in the two dryers shows significance difference. The highest nitrogen content of (3.83±0.00) was recorded for the solar thermal dryer compared to (3.33±0.00) obtained using PV/T dryer.

### 3.6 Cations and Heavy Metals Analysis

The same trend was observed for the concentrations of these elements in the dried tomatoes using both the PV/T and ST drying methods, there was great reduction in concentrations of the metals Ca, Mg, K, Na, and Fe Compared to their concentrations in the fresh tomatoes. Still for the tomatoes the concentrations obtained for the PV/T method of drying is higher when compared to those obtained for the ST, this also proved the PV/T is the best of the two methods for drying tomatoes refer to table 7

**Table 7: Comparing of Major Cations concentration in Fresh and Dry Tomatoes using PV/T and ST Drying methods**

| Element | Fresh Tomatoes concentrations of elements | PV Drying method Concentration of cations in dried Tomatoes | ST Drying method Concentration of cations in dried Tomatoes |
|---|---|---|---|
| Ca | 1,563.75 ppm | 1.358.25 ppm | 1,178.25 ppm |
| Mg | 336.5 ppm | 159.75 ppm | 103.5 ppm |
| K | 2,065.5 ppm | 1,313.75 ppm | 643.75 ppm |
| Na | 636.5 ppm | 312.25 ppm | 283.25 ppm |
| Fe | 1,359.75 ppm | 1359.5 ppm | 1,131.25 ppm |

For the concentrations of heavy metals in dry Tomatoes both the PV/T and ST show a similarity in terms of concentration from Table 4.15, it can be seen that all concentrations reduce in both PV/T and ST methods compared to fresh tomatoes concentration of the metals which signify the effect of both methods on the heavy metals' concentrations

**Table 8: Comparing of Heavy metals concentration in Fresh and dried Tomatoes using PV/T and ST drying methods.**

| Element | Fresh Tomatoes concentrations of elements | PV Drying method Concentration of heavy metals in dried tomatoes | ST Drying method Concentration of heavy metals in dried Tomatoes |
|---|---|---|---|
| Zn | 12.5 ppm | 5.25 ppm | 0 ppm |
| Cd | 3.75 ppm | 1.5 ppm | 2.5 ppm |
| Cu | 0 ppm | 0 ppm | 0 ppm |
| Ni | 5.75 ppm | 3.25 ppm | 0 ppm |
| Pb | 14 ppm | 5.5 ppm | 1.75 ppm |
| Mn | 14 ppm | 3.5 ppm | 0.5 ppm |
| Cr | 0 ppm | 0 ppm | 0 ppm |

## 4.0 CONCLUSION

The comparative performance evaluation of the Hybrid (PVT) and Conventional solar thermal dryer for drying tomatoes was conducted. The study was carried out using fresh tomato sample with 95% initial moisture content. During the experiment the basic weather parameters that determine the drying process were recorded, such as Wind Speed, Relative Humidity, Ambient Temperature and Solar Radiation on hourly basis. Results of the experiment conducted show that, the initial moisture content of the fresh tomato samples

is 95% and was reduces to 15% after drying. The result of the drying shows that the PVT hybrid dryer took 35 hours for drying of the tomatoes, while the conventional dryer took 37 hours. The result of the three models' shows that polynomial best describes the drying process of the tomato in both the PVT and conventional solar thermal dryer with the values as $R^2 = 0.9937$ and$R^2=0.9975$.
The comparative analysis of the two dryers shows that that the hybrid (PVT)dryer has more advantage than the solar thermal in terms of the result of the proximate analysis and quality assessment of the nutritional value of the dried sample.

Cations and heavy metals analysis carried out using solar thermal and PV/T hybrid dryer on fresh and dried tomatoes revealed that the concentrations of the elements detected in tomatoes dried using solar thermal and PV/T hybrid dryer is lower compared to the concentrations in the fresh samples

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