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Evaluation of Solar Dryers Thermal Performance and Rehydration Capacity of Dried Mango and Tomatoes Varieties

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Abstract:
The thermal performance of solar dryers (cabinet direct, cabinet mixed-mode and tunnel dryers), and rehydration capacity of dried mango and tomatoes were investigated in this study. Ambient and drying conditions, dryers' collector efficiencies, drying rate using equal loading density of 2.91 kg/m^2 of mango and tomatoes varieties and rehydration capacity at 50°C for 60 minutes were determined. Drying conditions varied in a day with maximum solar radiation intensity, ambient temperature, air velocity and minimum relative humidity of 1166 W/m^2, 36.8°C, 3.6 m/s and 26.2% respectively recorded at 13 hours. Tunnel dryer had significantly ($p<0.05$) higher collector efficiency of 57.5 and drying rates of 1.36 and 1.57 kg/h for mango and tomatoes respectively than respective lower values in cabinet dryers of 32.4-34.2% and drying rates of 0.11-0.13, and 0.17-0.22 kg/h. Similarly the tunnel dried samples had significantly ($p<0.05$) higher rehydration ratios of 4.5-5.3 in mango varieties and 5.1-5.5 in tomato varieties than lower values of 3.0-3.6 and 3.8- 4.3 respectively. Therefore, solar dryer performance and rehydration capacity of dried products are significantly affected by dryer type and design, sample composition/variety and weather conditions with tunnel dryer performing better performer than cabinet dryers. Hence, fabrication and use of solar tunnel dryers for reducing the alarming postharvest losses of agricultural produces in the country is highly recommended.

Keywords: *Solar drying, collector efficiency, performance, rehydration, drying rate, mango, tomato*

1. Introduction

Fruits and vegetables are important food components as they supply wealth of minerals, vitamins and antioxidants. Epidemiological studies have demonstrated a strong correlation between adequate consumption of fruits and vegetables with reduced risk of some major diseases such as cardiovascular, diabetes and certain types of cancer (Segura-Carretero et al., 2010). Postharvest loss of fruits and vegetables in developing countries is about 35-40% (Karim & Hawlader, 2005). Lack of appropriate postharvest handling and processing technology are among the contributing factors of PHL's (Perumal, 2007). Drying is a process that decreases the water activity in the product; inhibit the development of microorganisms, and decreasing spoilage reactions (Pisalkar et al., 2014). In addition, it reduces weight and volume; minimizes packaging, storage and transportation costs (Sagar & Suresh, 2010; Doymaz, 2014).

Sun drying is a common method for drying agricultural produces, especially in developing countries. However, the method is associated with in-built problems, since the product during drying is unprotected from rain, storm, windborne dirt, dust and infestation by insects, rodents, and other animals (Folaranmi, 2008). Consequently, the quality of dried products may be adversely affected, failing to meet the required local and international standards (Ivanova & Andonov, 2001). Furthermore, advanced mechanical drying methods such as freeze, drum and cyclone drying are not feasible in the developing countries due to their relatively high initial and operating costs. Based on those circumstances, more emphasis is now shifting towards the use solar thermal energy as an alternative source of energy for drying fruits, vegetables and grains (Eltief et al., 2007; Visavale, 2012). The attractiveness of solar dryers is further enhanced by its ability to dry the product rapidly, uniformly and hygienically with energy costs (Condori et al., 2001, Abraha et al, 2017).

Furthermore, it has been reported that, drying at higher temperatures may cause losses of some important nutrients especially volatile nutrients like vitamin C (Chua et al., 2000). Also, change of texture, and flavor and rehydration capacity (Praveenkumar et al., 2006; Mayor & Sereno 2004). Studying performance of different dryers such as collector efficiency, drying rates and quality of the dried products is of greater importance towards design, construction, and optimization of drying systems operations (Pardhi & Bhagoria, 2013). Rehydration is an important quality attribute for dried products and regarded as a measure of the degree of cellular and structural damage caused to the food during drying as influenced by processing conditions, pretreatment, and composition of samples (Bilbao-Sainz et al., 2005). The ability of food products to reconstitute depends primarily on the internal structure of the dried pieces and the extent to which the water-holding components (such as proteins and starch) have been damaged during drying (Krokida & Philippopoulos, 2005). Many studies have been conducted to evaluate solar dryer performance (Pardhi and Bhagoria, 2013; Doymaz, 2014) and rehydration ratio of fruits and vegetables (Ramallo and Mascheroni, 2012), Doymaz, 2014, Kumar - 2014, Akoy, 2014). However, there is limited information on performance of different solar dryers and rehydration capacity of mango and tomato in Tanzania. Therefore, this study was conducted to assess the solar dryer's performance, and rehydration capacity of dried mango and tomatoes in order to establish their optimum processing conditions.

2 Materials and Methods

2.1. Study Area

This study was carried out at Danida pilot project premises at Sokoine University of Agriculture (SUA), Morogoro Tanzania. All drying activities and performance tests were done at the premises whereas rehydration ratio experiments were conducted in the Department of Food Technology, Nutrition and Consumer Sciences Laboratory, SUA.

2.2. Materials

2.2.1. Plant Materials

Selected varieties of mango (Mangifera indica cv. Dodo, Viringe and Kent) and tomato (Lycopersicum esculentum cv. Tanya, Cal J and Onyx) were procured at physiological maturity and ripeness from selected farmers in Mlali, Morogoro, Tanzania.

2.2.2. Solar Dryers and Their Description

Two solar cabinet dryers: Cabinet direct dryer (CDD) and cabinet mixed modes dryer (CMD) were locally fabricated and one solar tunnel dryer (TD) (Innotech, German) was imported from Hoeinheim University in Germany and installed in the study area (Plate 1). The dryers consisted of two parts namely collector and a drying unit/tunnel. In addition, the tunnel dryers consist of small fans to provide the required air flow over the products to be dried. The dimensions for collector and drying section of CDD were (1.17 x 2.35 m) and (0.67 x 1.44 x 2.29 m), respectively while for CMD were [(1.03 x 1.16) + (90 x1.16 m) for extension] and [(1.13 x 1.19 x 1.23+ 0.99 x 1.23 m) for extension]. The tunnel dryer had dimension of 7.1 x 2 m and 10 x 2 m for collector and drying chamber respectively. Both collector and the drying units were covered with UV stabilized visqueen sheets and food grade black paint was used as an absorber in the collectors. The products to be dried were placed in trays in cabinet dryers and a single layer on a wire mesh in the tunnel dryer.

2.2.3. Methods

2.2.3.1. Research Design

Completely randomized design (CRD) was used to study the performance of the dryers. The effect of dryer type on drying temperature and humidity, collector efficiency, moisture removal, drying rates, and rehydration ratio were assessed and compared. The mathematical expression is shown in Equation 1.

$$y_{ij} = \mu i + \tau_i + \varepsilon_{ij} \ldots\ldots (1)$$

$$i=1, 2,\ldots, t, j=1, 2,\ldots,$$

Where μ is the overall mean, τi is the ith treatment effect (drying method) and εij is the random effect due to jth replication receiving ith treatment.

2.2.3.2. Evaluation of Dryers' Thermal Performance

The performance of the dryers was evaluated by the collector efficiency and drying time/rates in two different seasons; dry and rainy seasons. Tests were conducted between September and November, 2015 and 2016. Both tests were done without loading with products (no load tests) and started at 8:00 am and stopped at 6:00 pm. The drying time/ rate were determined by loading dryers with mango and tomato (load test) during the same seasons, periods and times. The important parameters affecting performance of the dryers were measured at no load test as follows;

2.2.3.3. Solar Radiation Intensity Measurement

The incident solar radiation was measured by solarimeter (Model SL 200, Romania). The solarimeter was placed in a fixed position between dryers and the readings were taken continuous from 8.00 am to 6.00 pm on every experimental day.

2.2.3.4. Temperature measurement

The temperatures at different points of collector and drying chamber were measured with thermocouples (Model HI 98704 K, J and T types) via a data logger, Hanna Instrument Inc, Romania), every 15 minutes. The ambient air temperature, temperature at the entrance of the solar collector, at the exit from the collector and the drying chamber were determined.

2.2.3.5. Air Velocity Measurement

The air velocity at the entrance of dryer was measured using Anemometer (Model EA 3000, Techno line Ltd, Romania) and the readings were taken at 15 minutes intervals.

2.2.3.6. Relative Humidity Measurement

Relative humidity for the inlet ambient air and the outlet air from the drying chamber were determined using thermo hygrometer (Model HI 8564, Hanna Instrument Inc., Romania) and readings were taken at 15 minutes intervals.

2.2.3.7 Determination of Collector Efficiency

Collector efficiency of the dryers was determined by using the Equation 2 as explained by Chowdhury et al. (2011).

$$\text{Collector efficiency } \eta_c = \frac{\rho VCp\Delta T}{AIc} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(Eq 2)}$$

Where, where (ρ) is the density of air (kg/m^3), (I_c) is the in solation on the collector, (ΔT) is the temperature elevation, (C_p) is the specific heat capacity of air at constant pressure (J/kg K), (V) is the volumetric flow rate (m^3/s), and (A) is the effective area of the collector facing the sun (m^3)

2.2.3.8. Determination of Moisture Content Change

Moisture loss was determined by measuring the initial weight of the samples before loading and after every hour following loading. Variation in moisture contents between initial and moisture content any given point was considered as moisture

2.2.3.9. Determination of Drying Rate

The drying rate was computed using Equation 3 as described by Itodo et al. (2002).

$$\text{Drying rate} = \frac{dM}{dt} = \frac{(Mi - Mf)}{t} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots . \text{(Eq 3)}$$

Where, Mi and Mf are the initial and final moisture contents (kg moisture/kg dry matter), respectively, t is drying time.

2.2.3.10. Rehydration Capacity

Rehydration experiments were performed as described by Maskan (2001). Approximately 5 g of dried samples was added to 400 mL distilled water, in a 500 mL beaker. The sample was withdrawn from the liquid every 10 minutes, and excess water was carefully removed by blotting on a tissue paper 4±5 times gently in order to eliminate the surface water, before weighing. The actual rehydration duration was 60 min. Weights of dried and rehydrated samples were measured using an electronic digital balance The rehydration ratio (RR) was calculated using Equation 4 described by Singh et al. (2010).

$$\text{Rehydration ratio} = \frac{W_r}{W_d} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(Eq 4).}$$

Where Wr is the weight of moisture (g) and Wd is the weight of dry sample (g)

2.2.3.11. Statistical Data Analysis

The data were analyzed by using R statistical package (R Development Core Team, Version 3.0.0, Vienna, Austria) for one-way analysis of variance to determine significant differences between factors at ($p<0.05$). Means were separated by Turkey's Honest Significant Difference at $p <0.05$.

3. Results and Discussion

3.1. Solar Radiation and Temperature Profile under No Load Test

Figure 1a show solar radiation intensity during experimental days with maximum average value of 1166 W/m^2 at 13 hours and minimum values in the morning and end of day at 7:00 hours and 17 hours respectively (Figure 1a). Intensity of the solar radiation remained approximately same for the everyday of the experiment performance. The temperature varies in relation with the solar radiation intensity. The dryer collector and drying chamber temperatures were much higher than ambient temperature during most hours of the day. The maximum collector temperatures of 60, 55.5 and much higher 83°C were recorded inside the cabinet direct dryer (CDD), cabinet mixed-mode dryer (CMD) and tunnel dryer (TD) respectively at 13 hours (Figure 1b). Similar trend was observed in the drying chamber temperature where, maximum values of 55.2, 50.5 and much higher 73.04 C were recorded in CDD, CMD and TD respectively (Figure 1c).

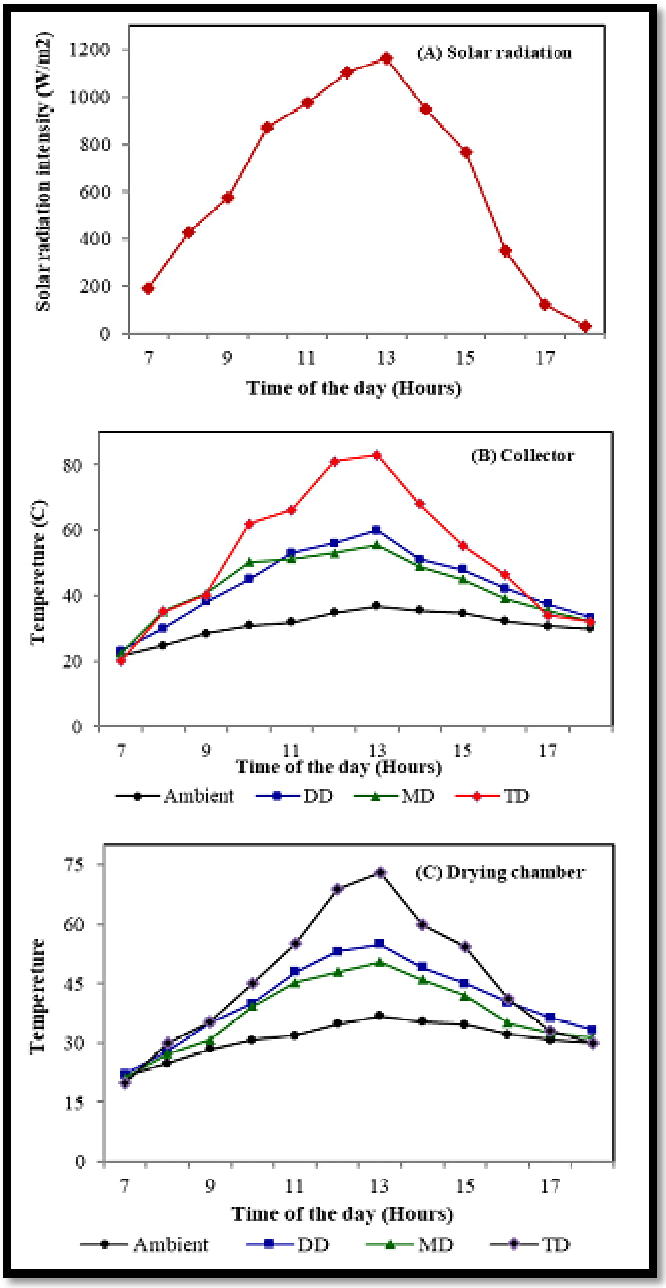

Figure 1: (a-c): Solar Radiation Intensity (a), Ambient and Collector Temperature (b) and Ambient and Drying Chamber Temperature (c) Inside the Dryers under No Load Condition during Experimental Days (N=3)

The findings revealed that solar drying temperature depends on solar radiation which vary in within a days, season and from years. Solar dryers generate higher temperatures than ambient due to their ability to trap radiant energy on solar collector and concentrates heat inside the drying chamber (Dadashzadeh, 2006). This suggest that solar radiation in the form of solar thermal energy may serve as an alternative source of energy for drying agricultural products such as fruits, vegetables, and grains. This procedure is especially applicable in the so called "sunny belt" world-wide, i.e. in the regions where the intensity of solar radiation is high and sunshine duration is long (Visavale, 2012). In Tanzania, solar energy resource is abundantly available almost throughout the year (GTZ, 2007). Being in a "solar belt", Tanzania receives between 2800-3500 hours of sunshine per year and has a global solar radiation between 4-7 kWh/m^2/day. The average solar flux based on 24 hours can be as high as 300W/m^2 or more (African Development Bank, 2015: Smart Solar Tanzania, 2019). With such a high level of solar energy resource, Tanzania is naturally suitable for application of solar energy as viable alternative sources of modern energy supply like mechanical dryer for drying agricultural produce especially in rural area (GTZ, 2007). Hassan (1995) recommended drying air temperature between 55 to 75°C for fruits and vegetables. Observed significant variation in heat generation between cabinet and tunnel dryers could be due to their different designs and mode of operations.

3.2. Temperature and Humidity Profile under No Load Test

Variation of the drying temperature and relative humidity inside the dryers under no load conditions are presented in Figure 2 (a-c). Relative humidity decreased with the increasing drying air temperature. Maximum ambient humidity of 53.9% was observed at 22.1° at 7:30 hours, which decreased to minimum value of 26.5% at 33.3°C between

12:00 and 13 hours and increased to 38.2 % at 18 hours (Figure 2 a). High relative humidity of 64.6% was observed inside the CCD in the morning which decreased to 0% between 11:00 and 13 hours at maximum temperature of 55°C and increased again to 38.2 % at 18 hours at temperature of 33.2°C (Figure 2 a). Similarly, relatively humidity of 57.4% were observed inside the CMD at 7:30 hours decreased to minimum values of 7 at maximum temperature of 50°C at 13 hours (Figure 2 b). Furthermore, relatively much higher values of 62.4 % was respectively in tunnel dryer at 7:30 hours which decreased to 0% at maximum temperature of 73°C at 13 hours and between 10:00 to 3:00 hours respectively (Figure 2 c).

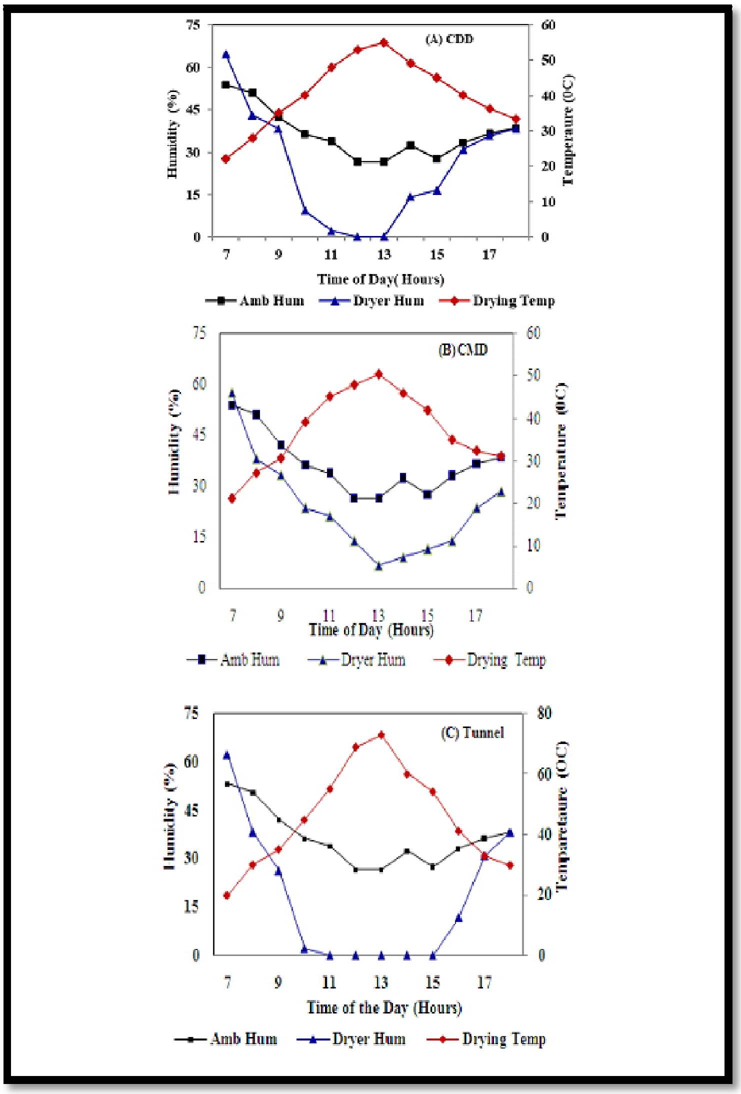

Figure 2: (a-c) Variation of Drying Air Temperature and Humidity Inside the Drying Chamber of Cabinet Direct Dryer (CCD)_a, Cabinet Mixed Mode Dryer (CMD) _b, and Tunnel Dryer (TD) _c During Experimental Days (N=3)

Temperature and humidity are among the most important factors determining how quickly the food dries. The generated high temperature inside the dryer lowers relative humidity than ambient conditions and thus its efficiency as a vehicle for removal of moisture resulting in increased drying rates (Dadashzadeh, 2006; Blair et al. 2007). Similarly, Bala et al. (2009) and Ayyappan and Mayilsamy (2010) found the drying processes being enhanced by the heated air at very low humidity. In tropical countries, solar dryers can be used to dry fresh produce when average relative humidity is below 50% during drying period (Infonet-biovision, 2012). The findings of this study suggest that, application of solar drying can be a better alternative solution to all drawbacks of open sun and expensive industrial dryers experienced by developing countries. Furthermore, higher temperature attained inside the dryer act as a deterrent to insect and microbial infestation (Bala & Janjai, 2009)

3.3. Collector Efficiency

Results for collector efficiencies for the three dryers are shown in Figure 3. There was significant ($p<0.05$) difference in thermal collector efficiency between the dryers. Tunnel dryer had significantly higher efficiency of 57.5% compared than statistically similar lower values in cabinet dryers (32.4-34.2%) suggesting that type and design of solar dryer has significant effect on the collector efficiency and overall dryer performance.

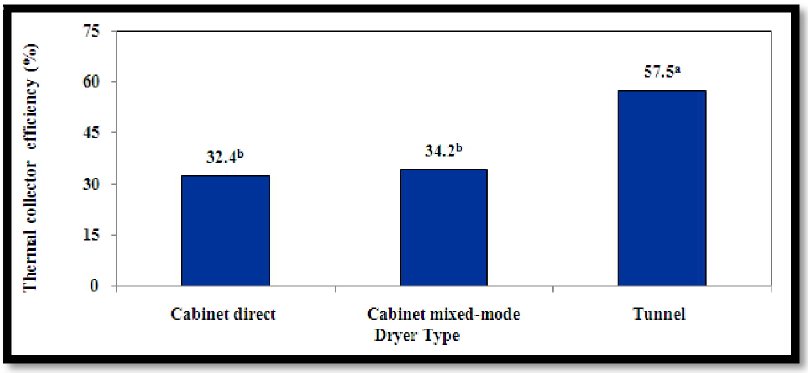

Figure 3: Collector Efficiencies of Solar Dryers. Data Presented as Arithmetic Means ± SD (N = 2). Different Letters in the Bars Are Significantly Different at P<0.05

The collector efficiency depends on meteorological parameters (direct and diffuse radiation, ambient temperature and wind speed), design parameters (type of collector, collector materials) and flow parameters (air flow rate, mode of flow) (Aboltins et al., 2015). Tunnel dryer uses forced airflow system which increases the energy output-input ratio and overall efficiency. Moreover, the larger collector surface area in the tunnel dryer than in cabinet dryers could have contributed to more energy output from the collector and thus increased the efficiency. The principal requirement of collector designs is a large contact area between the absorbing surface and air (Kalogirou, 2009). Since solar radiation and temperature are the key factors for solar dryer performance and vary with location and seasons, then the solar collector efficiency levels will also vary accordingly in some areas and seasons.

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3.4. Drying Kinetics at Load Test

3.4.1. Moisture Content Change

Figure 4 (a and b) shows the moisture content changes in mango and tomato with drying time in three dryers. There was a significant ($p<0.05$) variation in moisture reduction between cabinet and tunnel dryers. The initial moisture content of 79% was reduced to 16 % in all dryers with the tunnel dryer having the highest reduction per given unit time than the cabinet dryers. A shorter curved line observed for tunnel dryer compared to longer linear line shown by cabinet dryers which reflects longer drying time. Similarly, the initial moisture content of tomato 93.18% (FW) was reduced to 14.1% (FW) in all dryers with the tunnel dryer having higher reduction per given unit time coupled with shorter drying time (Figure 4).

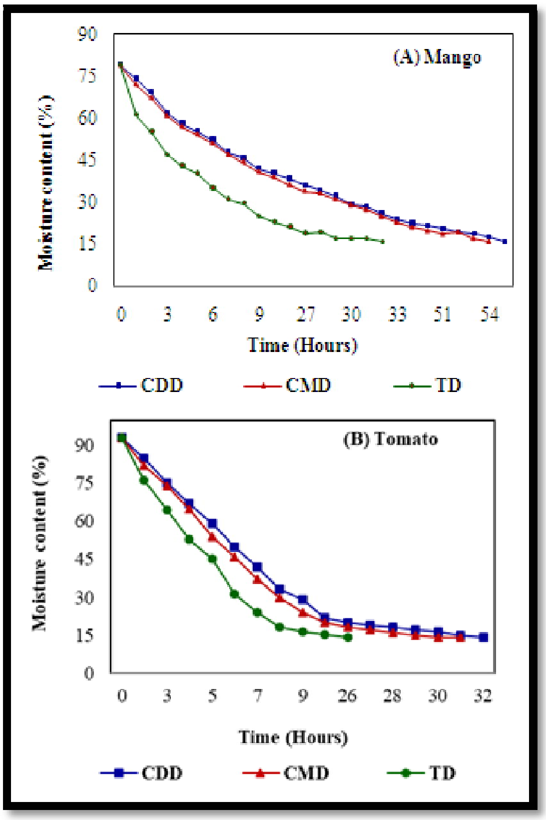

Figure 4: Variation of the Moisture Content of Mango (a) and Tomato (b) with the Time during Drying in Cabinet Direct (CDD), Mixed Mode (CMD) and Tunnel (TD) Dryers

These findings have revealed that, moisture content decreased with increasing drying time which agrees with other studies (Bala et al., 2009; Eze & Agbo, 2011). The removal of moisture prevents the growth and reproduction of microorganisms like bacteria, yeasts and molds causing decay and minimizes many of the moisture-mediated deteriorative reactions. It brings about substantial reduction in weight and volume, minimizing packing, storage, and transportation costs and enables storability of the product under ambient temperatures

3.4.2. Drying Times and Rates

The variations in drying rates between cabinet and tunnels dryers for both produce at similar drying conditions and loading density of 2.91 kg/m^2 were significant ($p<0.05$) (Table 1). Tunnel dryer took 32 hours to dry 58.2 kg of mango from moisture content of 79 to 16 % (FW) with mean drying rate of 1.36 kg per hour while direct cabinet (CDD) and mixed-mode (CMD) dryers took 55 and 54 hours to dry 9.6 and 8 kg of mango from same initial to final moisture contents ranges with mean drying rates of 0.13 and 0.11 kg/hour, respectively. Moreover, the dryer performed better in tomato than in mango whereby it took 26 hours to dry the same 58.2 kg of tomato from moisture content of 93.18 to 14% (FW) with mean drying rate of 2.06 kg/hour. The cabinet dryers took 31 and 32 hours to dry 9.6 and 8 kg of tomato respectively to the same initial and final moisture contents values with drying rates of 0.28 and 0.24 kg/hr respectively.

Fruit	Dryer	Drying time (Hours)	Drying rate (Kg/hour)
Mango			
	CDD	55^{a}	0.13^{a}
	CMD	54^{a}	0.11^{a}
	TD	32^{b}	1.36^{b}
Tomato			
	CDD	31^{a}	0.22^{a}
	CMD	32^{a}	0.17^{a}
	TD	26^{b}	1.57^{b}

Table 1: Drying Times and Rates of Mango and Tomato
Data Presented as Arithmetic Means ± SD (N = 2).
Means within Fruit/Vegetable in Column with Different Superscript Letters Are Significantly Different at P<0.05

The observed differences in drying kinetics (drying time and rate) between drying methods could greatly be influenced by temperature which is a determinant that affect the internal working principle of the dryer, the relative humidity of the drying air, airflow rates and material interconnection (Ajadi et al., 2007; Kaya et al., 2007). The drying air temperature had the greatest effect on the whole drying process, and drying time of fruits and vegetable within its increasing rate-period, constant rate-period and falling rate-period. Therefore, the better drying kinetics observed in tunnel dryers could be associated to its ability to collect more heat in the drying chamber which in combination with its constant uniform air circulation control, immediately removes moisture collected in the drying chamber (Hawlader et al., 2008). Previously Gewali et al. (2005) found similar better drying kinetics in tunnel dryer than solar cabinet dryers and thus accepted it to be suitable for drying almost all kinds of fruits and vegetables with satisfactory quality. Moreover, the variations in drying rates between mango and tomato under the similar drying conditions and loading density as observed in this study could be explained by their differences in moisture contents, structure and compositions. Composition and structure of the food influence the mechanism of moisture removal, for instance, the orientation of fibers in vegetables (e.g. celery) allow more rapid moisture movement along their length than across the structure. In short, moisture is removed more easily from intercellular spaces than from within cells (Alonge & Adeboye, 2012).

3.5. Rehydration Capacity

In both fruit and vegetable, the rehydration ratios increased almost linearly with time during the first minutes of experiments before it becomes almost constant toward the end (Figure 5 (a-b). Drying methods differed significantly ($p<0.05$) in rehydration ratio with tunnel dried samples having higher values of 4.5 in Dodo, 5.2 in viringe and 5.3 in Kent variety than respective lower values of 3.0-3.2, 3.1-3.3 and 3.2-3.6 in cabinet dryers (Figure 5 a-c)

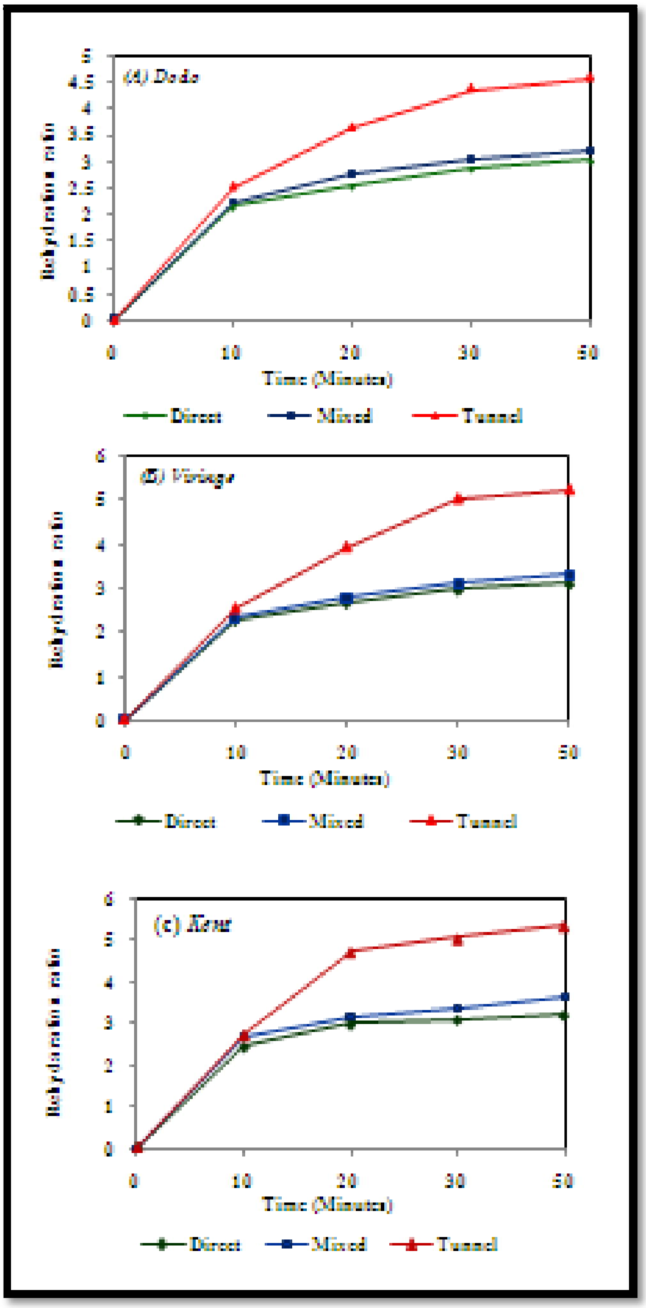

Figure 5: a-c Rehydration Ratio of Dried Mango Varieties at 50°C for 60 Minutes in Different Dryers

Moreover, a similar trend was also observed in tomato varieties were higher values of 5.1-5.5 ware obtained in tunnel dryer than lower values of 3.8- 4.35 in cabinet dried samples as depicted in Figure 8 a-c.

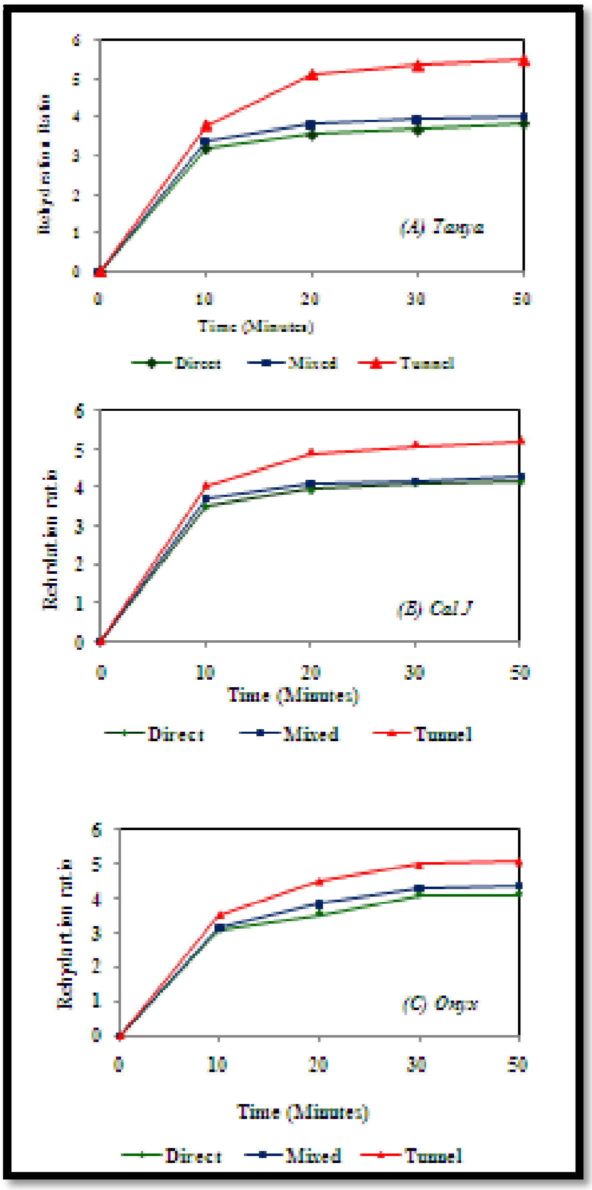

Figure 6: a-c Rehydration Ratios of Tomato Varieties at 50°C for 60 Minutes in Different Dryers

Figure 4 b shows the rehydration ratios of dried tomato varieties. The results show significant differences ($p<0.05$) in rehydration ratios between drying methods. Tunnel dried samples had higher ratio that ranged from 4.4 to 5.4 than cabinet dried ones that ranged from 4.5 to 5.4. Moreover, as in mango, varieties differed in significantly ($p<0.05$) within each drying method more pronounces in tunnel dried Tanya (5.4) and Cal J as well as between cabinet mixed mode dried Onyx (4.3) and Tanya (3.7) (Figure 7b)

Rehydration is an important quality attribute for dried products and the high ratio value means the dried product has a good quality because the pores allow water to reenter the cells (Noomhorm, 2007). The higher rehydration ratios in tunnel dried samples than cabinet than their cabinet counterparts imply solar drying methods have significant influence on the rehydration characteristic of the dried samples. A rapid and complete rehydration is an important property of dried products and is generally influenced by the sample composition (Jayaraman et al., 1992), method of processing, sample constitution, pre-drying treatment such as blanching and sulphiting, sample preparation prior to rehydration as well as extent of the structural and chemical changes induced by drying (Jayaraman and Das-Gupta, 1992; Krokida and Philippopoulos, 2005). The relatively higher rehydration capacity of tomato and tunnel dried samples than other products and cabinet dried samples, respectively, could be due to the shorter drying times associated with less textural damage during drying. Also, high drying rates for tunnel dryer do not allow for the cellular structure to collapse before it dries up. This allows for formation of a more porous structure, hence high capacity to imbibe water. The degree of cellular and structural disruption during drying, leads to loss of integrity and dense structure of collapsed capillaries with reduced hydrophilic properties, as reflected by the inability to imbibe sufficient water to rehydrate fully (Krokida and Philippopoulos, 2005; Pandey and Singh, 2011).

The physical damages caused include shrinkage, increased or decreased porosity, and damage to microscopic structure (Witrowa-Rajchert and Lewicki, 2006). Prolonged drying times (slow drying velocity) of the cabinet dryers increased shrinkage and toughness with reduced hydrophilic properties and hence low rehydration capacity of their products. Hence, rehydration has been considered as a measure of the induced damage in the material during drying

(Lewicki, 1998). Variation in rehydration capacity due to drying have also been reported in dried carrot (Strøm, 2011), dried tomato (Sacilik et al., 2006) and sweet potatoes (Pandey & Singh, 2011).

4. Conclusions

In a view of the findings it can be concluded that, the performance of solar dryers depends on weather conditions which also varies within a drying day, between drying methods and seasons. The performance was better during dry season than wet seasons and among the drying methods, tunnel dryer performs better than cabinet. Tunnel dried sample had higher rehydration capacity than cabinet dried sample suggesting less damage during drying due to its design and mode of operation leading to short drying time and high drying rates. Hence, fabrication and use of solar tunnel dryers during favorable weather condition to reduce the alarming postharvest losses of agricultural produces in the country is highly recommended.

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