Engineering Sciences
ISSN: 1308 7231 (NWSAENS)
ID: 2018.13.1.1A0402

Status : Original Study
Received: August 2017
Accepted: January 2018

Mohammed Gana Yisa
Adeshina Fadeyibi
Kwara State University, Malete-Nigeria
mgyisa@gmail.com; adeshina.fadeyibi@kwasu.edu.ng

DOI	http://dx.doi.org/10.12739/NWSA.2018.13.1.1A0402	
ORCID ID	---	0000-0002-4538-9246
CORRESPONDING AUTHOR	Adeshina Fadeyibi	

MODIFICATION AND EVALUATION OF AN ELECTRIC DRYER FOR HIGH MOISTURE VEGETABLES

ABSTRACT

Food wastage resulting from lack of facilities for drying and the unhygienic methods of processing are major causes of food shortage in supply chain. Thus, to address these issues, an existing electric dryer was modified for drying high moisture vegetables. The machine was evaluated for drying tomatoes with an initial moisture content of 63% (wb). A heating element was attached below the fan of the dryer to allow a through air circulation instead of the cross air flow pattern of the previous design. Four trays, with each having a capacity of $0.092m^3$, were loaded with 30.4kg of slice tomatoes at a rate of 7.6kg per tray and dried for 5h. Thermostat was used to regulate temperature and relative humidity in the drying compartment at 42°C and 11% RH. Control experiment was set up to determine the quality loss upon drying under sun for 5 h. Nutritional quality parameters of the dried products were determined using standard known methods. The results showed that actual volume of heated air delivered to the drying chambers, thickness of polyurethane used as lagging and power requirement for heating were $8.96m^3$, 38mm and 3000W, respectively. The nutritional quality loss in the sun dried samples was lower than the corresponding loss in the dryer. The modified dryer has 73% drying efficiency, which higher than the efficiency of the existing dryer.

Keywords: Design, Dryer, Performance, Tomatoes, Vitamin C

1. INTRODUCTION

Drying can be defined as the process of removing moisture from food substance by application of heat for the purpose of preservation. The need to prevent the activities of microorganisms in stored foods, which are capable of causing deterioration, is the major reason for food drying. Thus, drying helps ensure that microbial and enzymatic activities are reduced to extend storage life. While the range of foods that are dried is enormous, they can be divided broadly into two groups. The first is low value foods, such as grains and pulses, which are dried in large quantities [1]. The drying of this class of food is not associated with value addition and the major objective is usually to secure the product for an extended storage life. The second group is high moisture foods, like tomatoes, which are usually dried in small amounts [2]. In Nigeria, annual food losses from harvest to consumption are placed at 10% for grains and 35% for vegetables [3]. This calls for appropriate

How to Cite:
Gana Yisa, M. and Fadeyibi, A., (2018). Modification and Evaluation of an Electric Dryer for High Moisture Vegetables, **Engineering Sciences (NWSAENS)**, 13(1):70-84,
DOI: 10.12739/NWSA.2018.13.1.1A0402.

technologies in drying excess food. Locally, foods are dried on shelves placed above fire or stored in bans for an extended period of time. Indigenous dryers have also been developed using solar, biomass, electric and their hybrids based on the source of convective heat required for drying [4]. Solar, steam and biomass food dryers have been studied extensively probably because of cheaper and cleaner convective heat generation [5].

While solar, steam and biomass ensure that drying continues especially during power outage, certain anomalies can be introduced in the process. For instance, the cost of purchasing solar dryer and the high technology associated with biomass drying have made them unattractive by the local farmers [6 and 7]. The difficulty associated with temperature control in solar dryer makes the technology unsalable to the local farmers. They cannot be used at night and efficiency is usually low in cloudy or rainy weather. Very often, the dried products may be completely dried in one day, which may lead to mould growth initiation at night. They also do not lend themselves to being scaled up easily into larger units without introducing construction problems and fragile structure. To overcome some of these shortcomings, several mixed dryers, using backup source of heat from a burning fuel when necessary, have been proposed. Artificial dryers operating on the heat from burning wood, gas or electricity, can overcome the shortcomings of solar dryers. There is therefore the need for the use of artificial dryers like the electric dryers. Electric dryers can operate independent of weather conditions and can greatly control the drying process. It may be designed to greater capacity and can dry wider range of agricultural products. These are some benefits it presents, leading to its continual demand as conventional food dryer, despite dearth of electricity generation in most suburbs.

Effect of various drying techniques on nutritional quality of some foods has been studied [2, 6 and 10]. Alakali et al. [8] reported that the nutritional parameters of M. oleifera leaves dried in the shade varied closely with those dried in the oven at 40 and 50°C for 2 h. Microwave-drying was a better method for basil leave drying as it required shorter treatment time of 4 min and gave the best retention of protein and carbohydrates compared to oven-drying [9]. Ibupoto [6] reported that hot air drying was a better drying medium than sun and microwave oven drying methods in terms of quality retention. The research findings of Kiremire et al. [2] on the effect of vegetables drying techniques on nutritional content showed that solar drying is better than both oven drying and sun drying with respect to nutrient quality retention. Osmo-air drying method was reported as the best drying method for aonla because of better retention of ascorbic acid and sugars [10]. The research results of Ukegbu and Okereke [10] showed that solar drying retained more nutrients than sun drying and could be a better method of drying African spinach, fluted pumpkin and okra because it is relatively hygienic with reduced microbial load compared to sun drying.

Effect of electric drying, however, on the nutritional quality of food has not been extensively studied despite its effectiveness in promoting better drying kinetics and product quality than sun drying method [5]. Also, considering the staple nature of some high moisture foods, like tomatoes, together with associated short shelf life [11], any drying method for the produce cannot be over looked. Besides, there is no reported research on the performance evaluation of electric dryer, specifically designed for high moisture fruits and vegetables. The design of electric dryers have been reported but in most cases with low efficiency [12]. In a particular design, the heating element was placed above the fan and the body of the dryer was made of wood, thus affecting the drying rate due to poor insulation [12]. There is therefore the need to readdress this technology for improved efficiency. The objective of this research was to design, fabricate and test an electric dryer for drying high moisture vegetables, such as tomato.

2. RESEARCH SIGNIFICANCE

This paper is about the replacement and evaluation of an electric dryer for high humidity vegetables. Also, in this research, an electric dryer was designed, fabricated and tested. The article is intended to shed light on the researchers who will be doing vegetable drying.

3. MATERIALS AND METHODS

3.1. Description and Limitations of the Existing Dryer

The existing dryer was designed and fabricated for use in drying high moisture produce, like tomatoes, fresh corn and okra, at a capacity of 0.078m^3. The heating element was placed above the fan and the body of the dryer was made of wood, which may affect the drying rate due to poor insulation. A chimney hole was placed just above the fan through which heated air can escape. A cross flow air circulation pattern was used causing slower movement of heated air towards the tomatoes. There was no provision for the regulation of temperature inside the drying chamber, and as such monitoring of drying rate was difficult. Also, the heated air blows upwards and escapes through the chimney hole.

3.2. Modification Introduced

The capacity of the drying chamber was increased to accommodate more produce unlike the type reported by Yisa et al. [12]. The heating element was placed below the fan so that heated air can be directed towards the produce in a through circulation manner instead of the cross flow pattern used in the previous design. Thermostat was used to monitor inside temperature of the dryer; but this arrangement was not provided in the previous design. Power rating of the heater used was increased from 750 Watts to 3000 Watts. Other modifications in the current design are the use of galvanised iron sheet in construction of main frame of the electric dryer to replace the wooden material used previously [12]. Also, polyurethane was used as insulating materials all over the body of the dryer to prevent heat losses and Light bulb was fixed inside the drying chamber to ensure visibility at night.

3.3. General Features of the Modified Electric Dryer

The principle of direct heating was employed and the energy required in the process was supplied by electrical energy, which was converted to heat energy by the heating element in the drying chamber. Other parts of the electric dryer are front cover, base, outer casing, fan and heating element and water controlling tray. The inner casing was made of galvanised iron sheet riveted to plywood, which formed the outer casing. The capacity of the dryer measured 0.64m×0.64m×0.92m in dimension.

3.4. Design Assumptions and Considerations

The dryer was designed to operate in batches of 30 kg of tomatoes in 5 h. The moisture content and bulk density of the tomatoes used were 63% and 288.5kg/m^3 [1] and this information was considered in this design. In designing the blower, 20% excess air was allowed for freeboard. The blower was equipped with three blades of length 0.1m and width 0.03m attached to an electric motor (1440 rpm) of 20mm shaft diameter. Galvanised iron sheet (2mm thickness) and polyurethane used for construction have thermal conductivity of 36W/m^{o}C and 0.25W/m^{o}C, respectively. The initial temperature of measurement was 42^{o}C. The distance between heating chamber and tray was assumed 3000mm.

3.5. Equipment and Materials Used

The equipment and materials used in the design of the electric dryer include: electric heater (3000 Watts power rating), which generated the heat required in the drying process. Galvanised iron sheet (gauge 20) was used in construction of the main body, including the wall of the dryer so as to address the likelihood of corrosion. A 20mm×20mm square pipe was considered for the stand inside the drying compartment and positioned where the trays were mounted. Others were axial fan, mounted directly on a motor shaft, that forces air from the heat source into the drying chamber was used. The water collection trays were also made of galvanised iron sheet, and a depth of 50mm was allowed for effective water collection. The drying trays were square in shape and made from stainless steel to prevent food contamination.

3.6. Design Analysis of Dryer Components

3.6.1. Predesign Analysis

Spherically shaped tomatoes of equal length and varying diameters were used in this investigation. The expression given in Equation (1) was used to determine the average diameter of the 100 randomly selected tomatoes. The area of the drying tray and the total volume occupied by the tomatoes were determined from Equation (2) and Equation (3), respectively [13].

$$D_m = \sum_{i=1}^{n} \frac{d_i}{n} \qquad (1)$$

$$T_a = n\left(\pi {D_m}^2\right) \qquad (2)$$

$$B_t = hT_a \qquad (3)$$

where,

D_m =average diameter of the tomatoes (mm)

d_i=diameter of ith tomato (mm)

n=total number of randomly selected tomatoes (100)

T_a =total surface area of drying tray (mm^2)

h =height between tray to the top of the tomatoes slice on the tray (mm)

B_t =total volume occupied by the tomatoes (mm^3).

3.6.2. Blower Design

An axial flow fan, which blows air parallel to the axis of rotation of the blade, was used to move air into the dryer. The velocity of air circulation was computed from the expression in Equation (4). Also, the actual volume of heated air delivered to the drying chamber by the blower was determined from the expression in E Equation (5).

$$C_a = \frac{\pi DN}{60} \quad (4)$$

$$V_a = lwC_a \quad (5)$$

where,
C_a=peripheral speed of the blade (m/s)
V_a=actual volume of heated air delivered to the drying chamber (m^3)
D=diameter from the centre of the shaft to the top of the blade (m)
N=speed of the blower (rpm)
l =length of the blade (0.1m)
w =width of the blade (0.03m).

3.6.3. Thickness of Lagging Material (Polyurethane)

Polyurethane was used as a lagging material to prevent heat loss through openings and walls of the electric dryer. The apparent heat loss was first computed by assuming that air film close to the inner wall of the dryer and atmospheric air film close to the outside wall offer no restriction to the heat flux across the dryer walls. The thickness of the polyurethane materials was then determined from Equation (6).

$$Q_a = T_a \frac{(\theta_1 - \theta_2)}{\sum_{i=1}^{n} {x_i}/{k_i}} \quad (6)$$

Where,
Q_a=Heat loss by stainless steel (28.3W)
k_i=thermal conductivity of material of ith construction
θ_1=initial temperature (42°C)
θ_2=temperature of air after cooling (28°C)
x_i=thickness of materials of ith construction
(x_1=2mm and x_2=unknown).

3.6.4. Volume of Heating Chamber

The volume of the heating compartment of the electric dryer was determined from Equation (7). Also, the total volume of the inner part of the dryer was computed as the sum of the volume of heating chamber, volume occupied by the tomatoes, volume between trays and volume of water trough, as expressed in Equation (8).

$$V_h = l_t d_{ht} \quad (7)$$

$$V_{in} = \sum V_h, B_t, J_t, H_w \quad (8)$$

where,
V_h= Volume of heating chamber (mm^3)
l_t=length of tray (mm)
d_{ht}=distance between heating chamber and first tray (mm)
V_{in}=total volume of the inner part of the tray (mm^3)
J_t=volume occupied by tomatoes slices (mm^3),

H_w=volume of water trough (mm^3).

3.6.5. Amount of Water Removed and Quantity of Air Required to Remove Water

The amount of water removed from the tomatoes due to drying was determined from Equation (9). The drying condition used was 63°C and 50 RH, and drying was carried out until 10% moisture content was reached.

$$M_w = m_t(1 - w_1)/(1 - w_2) \quad (9)$$

where,

m_t= weight of tomatoes (kg),

w_1 = moisture content before drying (63%, wb)

w_2 =moisture content after drying (10%, wb).

The amount of air required to remove bounded water from the tomatoes was determined using average weather data obtained from previous meteorological data from 1980 to 1999 [12]. The data showed a dry bulb temperature (28°C), a wet bulb temperature (18-19°C) and 73% relative humidity (RH). The psychometric chart was used to determine the initial air moisture condition, from 28°C dry bulb temperature and 50% RH, as 0.008kg/kg. On heating the temperature increased to 42°C and RH decreased to 11%. When the heated air reaches saturation point, the final moisture content of the drying air was 0.013kg/kg. Thus, with the help of this information, the required amount of air needed to remove water from the tomatoes was computed from Equation (10). Also, the volume of air was computed according to Equation (11) [12].

$$M_a = \frac{M_w}{m_f - m_i} \quad (10)$$

$$V_a = \frac{M_a}{\rho} \quad (11)$$

where,

M_a =mass of air (kg)

m_f =final moisture content of the drying air (kg/kg)

m_i =initial moisture content of the drying air (kg/kg)

V_a =volume of air (m^3) ρ =density of air (1.29kg/m^3).

3.6.6. Heat Required for Vaporisation

The heat required to vaporise 1 kg of the moisture content of tomato was determined using the empirical relationships in Equation (12) and Equation (13).

$$H_t = H_r + H_l \quad (12)$$

$$H_r = (T_v - T_m)l \quad (13)$$

where,

H_t =total heat required for vaporisation (kJ)

H_r =heat required to increase air temperature to vaporisation temperature

H_l =latent heat of water at 63°C (2359kJ/kg)

l =specific heat of material (3.98kJ/kg.K)

$(T_v - T_m)$ = temperature difference heated air (vaporisation) and tomatoes (atmospheric) (K).

3.6.7. Heat and Mass Transfer Rates of Dryer and Drying Period

The heat and mass transfer rates of the electric tomatoes dryer were determined from the relationships in Equation (14) and Equation (15). In computing the mass rate, it was assumed that the mass transfer coefficient from a free water surface of the tomatoes into air is numerically equal to the heat transfer in the reverse direction. The psychometric chart was used to determine the humidity of air at 11% and 63°C and at 28°C as 0.013kg/kg and 0.08kg/kg, respectively.

$$Q = h_s T_a (T_v - T_m) \quad (14)$$

$$M_c = k T_a (H_s - H_a) \quad (15)$$

where,

h_s =surface heat transfer coefficient (83 J/(m^2.s.°C)

T_a =area of the drying tray (m^2)

k =mass transfer coefficient (kg/m^{2}s)

H_s =saturated humidity at 11% and 63°C (0.013kg/kg)

H_a =air humidity at 11% and 28°C (0.08kg/kg)

M_c =mass transfer rate (kg/s)

Q =heat transfer rate (J/s).

The period required for drying 30.4kg of tomatoes using the modified electric dryer was computed from Eq. (16).

$$p = \frac{M}{\left(\frac{\partial w}{\partial p}\right)} (w_i - w_f) \quad (16)$$

where,

p =drying period (h),

w_i =initial moisture content of tomatoes (63%)

w_i =final moisture content of tomatoes (11%)

M =amount of tomatoes dried matter (30.4kg)

$\frac{\partial w}{\partial p}$ =drying rate constant (1.09x10^{-3}kg/h).

3.6.8. Quantity of Air Supplied to Heating Chamber and Power Required For Heater Selection

The amount of air supplied by the blower to the heating chamber of the dryer was determined from the relationship expressed in Equation (17).

$$\beta_b = \frac{M_a}{p\rho} \quad (17)$$

where,

β_b =quantity of air supplied by the dryer (m^3/h)

M_a =amount of air required to remove water from tomatoes (kg)

p =drying period (h)

ρ =specific weight or bulk density of air (1.29kg/m^3).

The power requirement for selecting the capacity of the heating element was computed using Equation (18). Based on this, an electric heater of 3000 Watt rating was selected and used in the construction of the electric dryer. In order to take care of heat losses between the dryer walls and the surrounding, 5% additional heating capacity was allowed. Also, the technical characteristics of the modified electric tomatoes dryer is shown is Table 1.

$$PH = \frac{kH_t}{p} \quad (18)$$

where,

PH =power required for heater selection (kW)

H_t=heat of vaporisation of tomatoes (kg)

p =drying period (h)

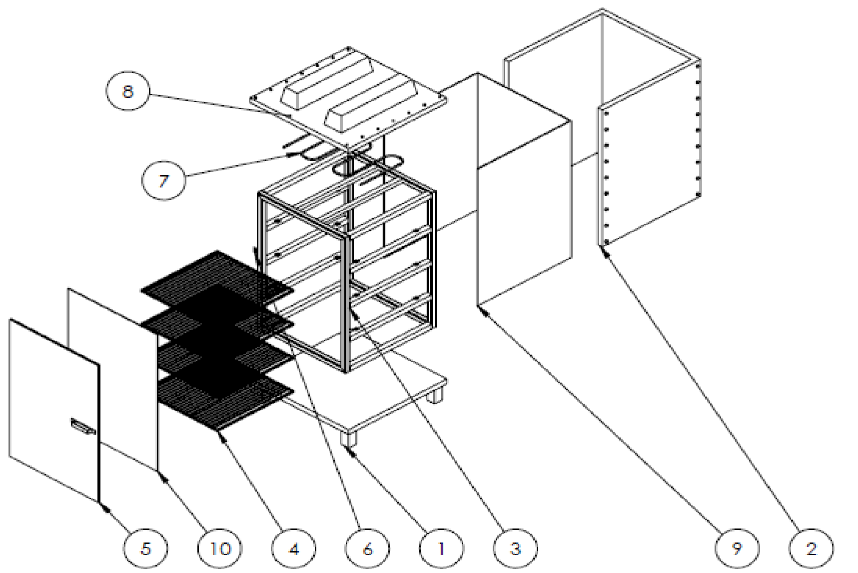
k =5% allowance=1.0

Table 1. Technical characteristics of the dryer

s/n	Design Analysis	Unit	Value
1	Predesign analysis:		
	a) Diameter of tomatoes	m	0.031
	b) Total surface area of drying trays	m^2	1.232
	total volume occupied by tomatoes	m^3	0.011
2	Blower design:		
	a) Velocity of air circulation	m/s	8.3
	b) Actual volume of heated air delivered to the drying chamber	m^3/s	8.964
3	Thickness of lagging material	mm	38
4	Volume of heating chamber	m^3	0.092
5	Volume of inner part of dryer	m^3	0.279
6	Amount of water removed	kg	18.02
7	Quantity of air required to remove water	m^3	2.79×10^3
8	Heat required for vaporisation	kJ	4.68×10^4
9	Heat and mass transfer:		
	a) Heat transfer	J/s	3.58×10^3
	b) Mass transfer	kg/s	5.11×10^{-4}
10	Drying period	H	4.622
11	Quantity of air supplied to heating chamber	m^3/h	558.9
12	Power requirement for heater selection	kW	2.951 (3000W)

3.6.9. Drawing of Electric Dryer

The exploded view, isometric drawing, third angle projection and sectional view of the electric dryer are shown in Figures (1) to (4), respectively.



1. Wooden stand 2. Wooden casing 3. Frame
4. Tray 5. Wooden door 6. Hindge
7. Filament 8. Control unit 9. Metal casing
10. Metal casing part

Figure 1. Exploded view of the electric dryer

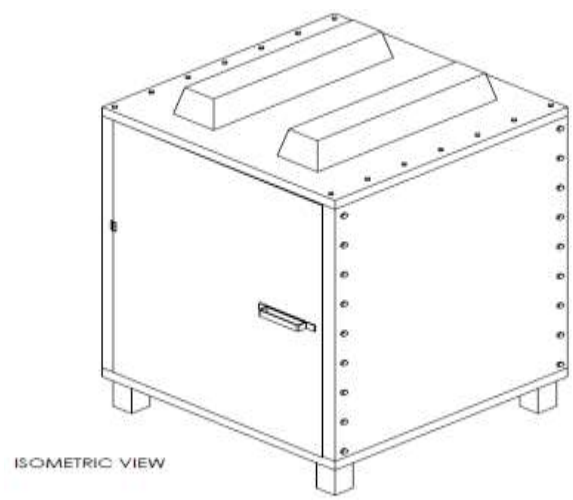


Figure 2. Isometric view of the electric dryer

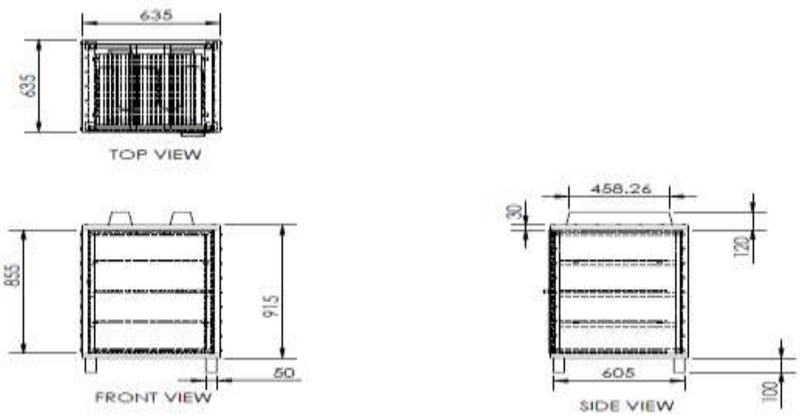


Figure 3. Third angle projection of the electric tomatoes dryer

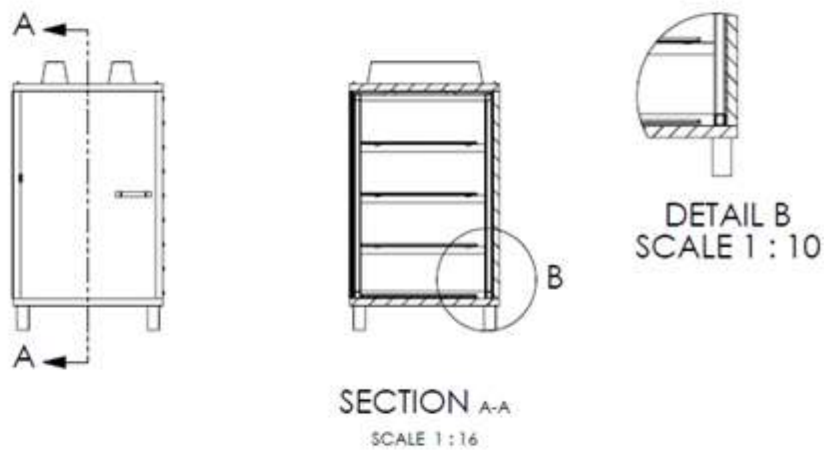


Figure 4. Sectional view of the electric dryer

3.7. Performance Evaluation of the Modified Dryer

3.7.1. Sample Preparation and Drying Efficiency

30.4kg of tomatoes were bought from Minna market and washed to remove dirt. Each tomato was then sliced into five pieces or more according to size. The slices were spread on four drying trays and placed in the drying chamber at a loading rate of 7.6kg per tray. The heating element and blower were then switched on for drying to commence. The weight of tomatoes on each tray was determined at an interval of 1 hour for a drying period of 5 h before and after loading. A control experiment was setup for an equivalent amount of slice tomatoes and dried under the sun at the same interval for a period of 5 h. The thermostat was used to regulate the temperature in the drying compartment to 42°C and 11% RH. The efficiency of the modified electric tomatoes dryer was determined from Equation (19) and Equation (20).

$$\varepsilon = \frac{H_t}{H_a} \times 100\% \quad (19)$$

$$H_a = e(T_1 - T_2)m \quad (20)$$

Where

ε =efficiency of the electric dryer (%),

H_t =theoretical heat required for tomatoes drying (4.68×10^4kW)

H_a =actual heat used in drying tomatoes (kW)

c =specific heat of air (1 $kJkg^{-1o}C^{-1}$)

m =mass of air used (3,604.6kg),

T_1=temperature tomatoes inside the dryer (regulated by thermostat, 42°C)

T_1=temperature of tomatoes after cooling (28°C).

Thus

H_a was computed as,

$$H_a = 1(42-28)\times 3{,}604.6 = 50{,}464.4$$ kJ

$$\varepsilon = \frac{4.68\times10^4}{50{,}464.4}\times 100\%$$

$$\varepsilon = 73\%$$

Therefore, the modified electric dryer has efficiency of 73%.

3.7.2. Moisture Content and Dry Matter Determination

The moisture content and dry matter of slice tomatoes was determined after every one hour of drying per tray using Equation (21) and Equation (22). The method was repeated for the control experiment. The experiment was conducted in triplicate and average values were computed.

$$MC = \frac{M_{ft}-M_{dt}}{M_{dt}}\times 100\% \quad (21)$$

$$DM = \frac{M_{ft}}{1+MC}\times 100\% \quad (22)$$

where,

= moisture content (%) (db)

DM =dry matter (%)

M_{ft} =mass of slice tomatoes before drying (kg)

M_{dt} =mass of slice tomatoes after drying (kg).

3.7.3. Determination of Ash, Vitamins C and A contents

Standard laboratory methods described by Onwuka [14] were used to determine the ash, vitamins C and A contents of the slice tomatoes after every one hour of drying per tray.

4. RESULTS AND DISCUSSION

Effects of drying tray and period on quality of slice tomatoes were shown in Figs 5 to 8. The effectiveness of the drying medium was tested by arranging four similar trays in the dryer as drying chambers. It was noticed that drying of sliced tomatoes was not the same in all trays probably due to their varying positions away from the blower. For instance, the dry matter was retained more in Tray 4 than the other trays and control experiment. It is likely that this is caused by effective distance between the tray and the blower. It can be seen that dry matter decreases with drying period regardless of tray position along heated air and drying medium, as expressed by the control experiment (Figure 5).

Also, since it is difficult to control the heat of the sun, it is as much expected that tomatoes samples placed under the sun will retain less dry matter. Similarly, moisture content of the tomato sample also decreases generally with drying period irrespective of the tray position along heated air and drying medium (Figure 6). The moisture retention performances of first, second and third trays are comparable, but this is at variance with the Tray 4, which retains less moisture than even the control experiment.

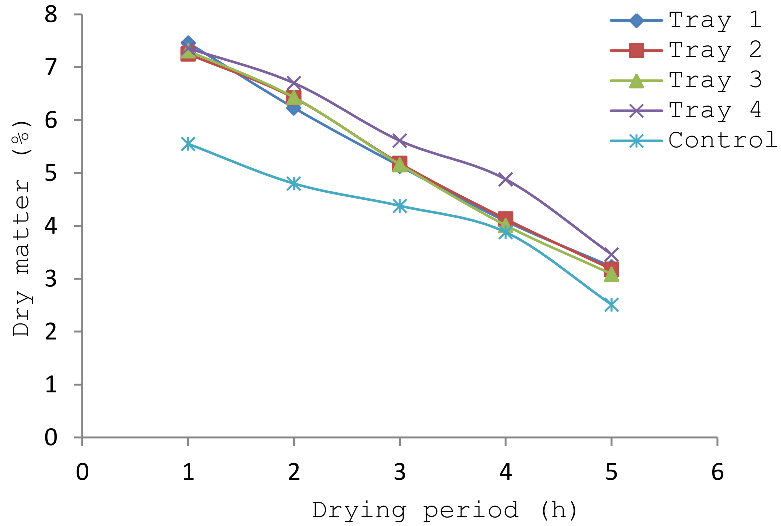


Figure 5. Effect of drying period on dry matter of tomatoes

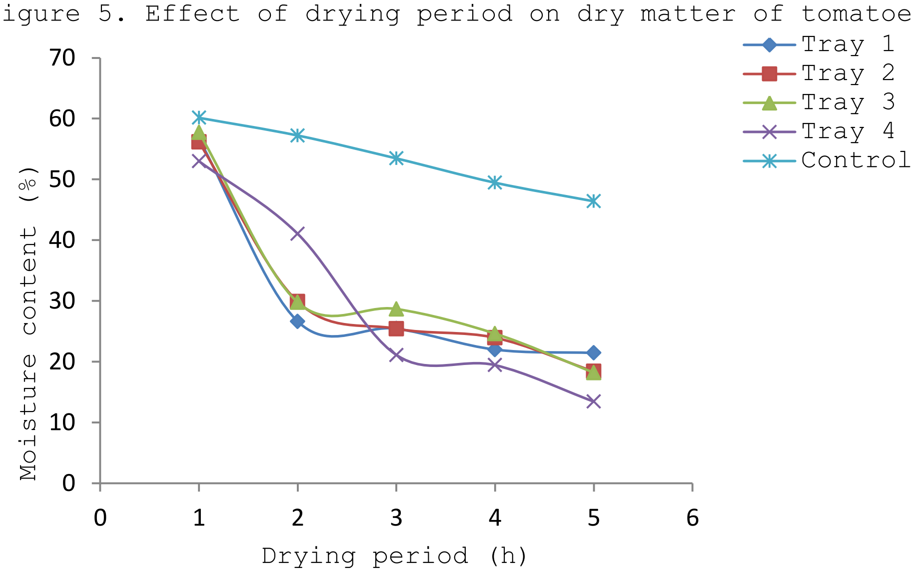


Figure 6. Effect of drying period on moisture content of tomatoes

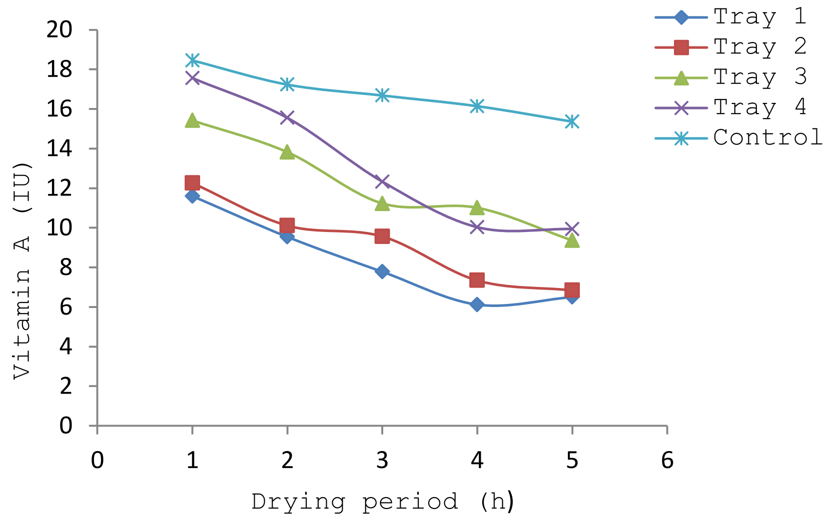


Figure 7. Effect of drying period on vitamin A content of tomatoes

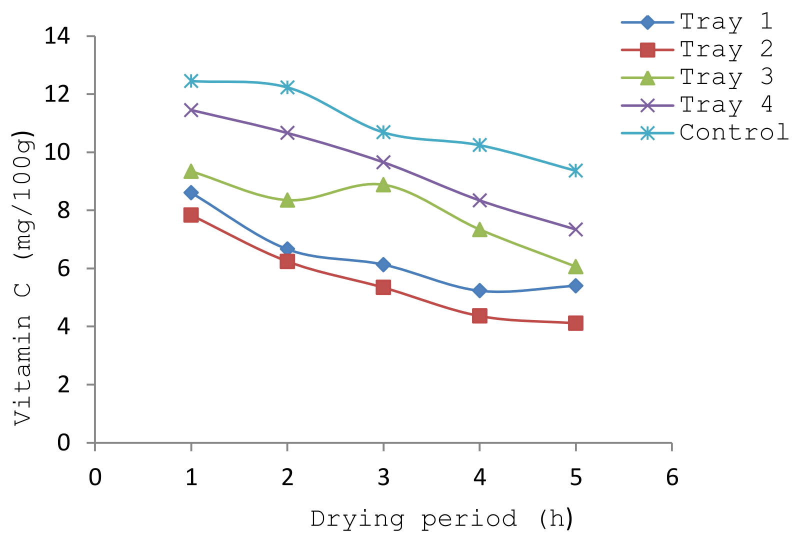


Figure 8. Effect of drying period on dry matter of tomatoes

Vitamins A and C of tomatoes decreased generally with drying period irrespective of the tray position along heated air and drying medium (Figure 7 and Figure 8). Vitamin A retention performance of Tray 1 was low probably due to their volatile nature as they are exposed closer to the heated drying air. The tomato slices in the second, third and fourth trays relatively farther away from the blower retained more vitamins. In a similar investigation, Ibupoto [6] reported that hot air drying was a better drying medium than sun and microwave oven drying methods in terms of quality retention. Microwave-drying was a better method for basil leave drying as it required shorter treatment time of 4 minutes and gave the best retention of protein and carbohydrates compared to oven-drying [9].

5. CONCLUSION

Drying of staple foods is essential for food security and sustainability. Electric drying techniques can be considered as one of the most important methods of sustaining food demands in growing population. In this research, an electric dryer was designed, fabricated and tested. The results showed that volume of heated air, thickness of lagging material used, volume of heating chamber, amount of heat transferred and power required of the heating element were 8.96m/s, 38mm, 0.092m^3 and 3000W, respectively. The nutritional quality of the dried tomato samples in all the trays decreased generally with drying period irrespective of the tray position along heated air and drying medium with 73% efficiency. The quality control samples also decreased with drying period, but performed poorly compared to the electrically dried samples. This implies that electric dryer is better for drying high moisture fruits and vegetables than sun drying for better quality retention.

ACKNOWLEDGEMENT

We are grateful to Mrs. Maymunah Audu Abubakar for assisting in data collection.

REFERENCES

1. Rice, O.A., Rice, P., and Taylor, S.R., (1993). Tropical Crops in West Africa. 2nd ed., The Macmillan press ltd. Pp. 56.
2. Kiremire, B.T., Musinguzi, E., Kikafunda, J.K., and Lukwago, F.B., (2010). Effects of Vegetable Drying Techniques on Nutrient Content: A Case Study of South-Western Uganda. Af. J. Food, Agric. Nutri. Develop. 10(5):2587-2600.
3. Hall, A.S., (1988). Machine Design (Theory Problem). Schaums online series. 1988, Pp. 367.
4. Asiedu, J.J., (1988). Processing Tropical Crops, A Technological Approach. London, Macmillan Press, Pp. 35.
5. Chua, K.J. and Chou, S.K., (2003). Low-cost Drying Methods for Developing Countries. Trends in Food Sci. & Techn. 14:519–528.
6. Ibupoto, N.P., (2007). Effect of Various Drying Methods on Nutritional Quality of Okra Vegetable. National Agricultural Research Centre.
7. Pragati, S. and Dahiya Dhawan, S., (2003). Effect of Drying Methods on Nutritional Composition of Dehydrated Aonla Fruits During Storage. Plant Foods Hum Nutr, 58:1. doi:10.1023/B:QUAL.0000040332.98384.c4
8. Alakali, J.S., Kucha, C.T., Rabiu, I.A., (2015). Effect of Drying Temperature on the Nutritional Quality of Moringa Oleifera leaves, Af J. Food Sci. 9(7):395-399.
9. Danso-Boateng, E., (2013). Effect of Drying Methods on Nutrient Quality of Basil (Ocimum viride) Leaves Cultivated in Ghana. Inter Food Res. J., 20(4):1569-1573.
10. Ukegbu, P.O., Okereke, C.J., (2013). Effect of Solar and Sun Drying Methods on the Nutrient Composition and Microbial Load in Selected Vegetables, African Spinach, Fluted Pumpkin and Okra. Sky J. Food Sci., 2(5), pp:35-40, July, 2013.
11. Fadeyibi, A., Osunde, Z.D., Agidi, G., Idah, P.A., Egwim, E.C., (2016). Development and Optimisation of Cassava Starch-Zinc-

Nanocomposite Film for Potential Application in Food Packaging. J. Food Process. & Techn., 7:591. doi:10.4172/2157-7110.1000591.
12. Yisa, M.G., Idah, P.A., Alabadan, B.A., (1998). Development of an Electric Dryer for Biomaterials. Nig. J. Biotech., 9(1):92-100.
13. Fadeyibi, A., Osunde, Z.D., Ussaini, M.S., Idah, P.A., Balami, A.A., (2012). Evaluating Monolayer Moisture Content of Rubber Seed Using BET and GAB Sorption Equations, Int. J. Farm & Al. Sci., 1(3), 72-76.
14. Onwuka, G.I., (2005). Food Analysis and Instrumentation Theory and Practice. University of Agriculture, Umudike, Nigeria Press, 162-204, ISBN: 978047686.