GSC Advanced Research and Reviews
eISSN: 2582-4597 CODEN (USA): GARRC2
Cross Ref DOI: 10.30574/gscarr
Journal homepage: https://gscarr.gsconlinepress.com/

(RESEARCH ARTICLE)

DETERMINATION OF THE APPROPRIATE DRYING PARAMETERS, STORAGE DURATION AND PACKAGING MATERIAL FOR TOMATO FRUIT USING FLUIDIZED BED DRYER

Abdulfatai Yusuf [1], Wasiu, Jimoh [2], Segun Emmanuel Sunmonu [3,*], Khadijat Omotayo Tajudeen [4], FaroukMuazu [4], Umar Sanda SuluGambari [5], Kabir Muhammad [4] and Hamza Abdullahi [2]

[1] Department of Agricultural and Bio-Resources Engineering, Federal University of Technology Minna.
[2] Department of Land and Water Engineering, National Centre for Agricultural Mechanization (NCAM), Nigeria.
[3] Department of Engineering and Scientific Services, National Centre for Agricultural Mechanization (NCAM), Nigeria.
[4] Department of Farm Power and Machinery, National Centre for Agricultural Mechanization (NCAM), Nigeria.
[5] Department of Planning Monitoring and Evaluation, National Centre for Agricultural Mechanization (NCAM), Nigeria.
* Corresponding Author: sunmonu.s@ncam.gov.ng

GSC Advanced Research and Reviews, 2026, 28(03), 001–015

Publication history: Received on 21 July 2026; revised on 29 August 2026; accepted on 31 August 2026

Article DOI: https://doi.org/10.30574/gscarr.2026.28.3.0213

ABSTRACT

Tomato is a highly nutritious but perishable crop that experiences significant postharvest losses due to its high moisture content and inadequate preservation methods. This study evaluated the effects of fluidized bed drying parameters, packaging materials, and storage duration on the quality of dried tomato. A Box–Behnken response surface design was employed to optimize three drying variables: temperature (55–70°C), hot air velocity (0.8–1.2 m/s), and slice thickness (3–7 mm). Fresh tomato slices were dried to a water activity below 0.6, after which the optimized samples were packaged in glass jars, plastic containers, and low-density polyethylene bags and stored under ambient conditions for five months. Proximate composition, lycopene, β-carotene, microbial quality, and sensory attributes were evaluated monthly. The results showed that drying parameters significantly ($p < 0.05$) influenced the nutritional composition and carotenoid contents of dried tomato. Increasing drying temperature and air velocity reduced moisture content while improving lycopene retention but resulted in lower β-carotene content. The optimum drying conditions were identified as 70°C drying temperature, 0.9 m/s air velocity, and 5 mm slice thickness, producing dried tomato with desirable nutritional quality and low moisture content. During storage, moisture content, carbohydrate, fat, and microbial counts increased, whereas protein, ash, crude fibre, lycopene, β-carotene, and sensory quality gradually declined. Among the packaging materials, glass jars and plastic containers provided better preservation of product quality than low-density polyethylene bags, while unpackaged samples deteriorated most rapidly. The study demonstrates that optimizing fluidized bed drying conditions combined with appropriate packaging can effectively enhance the quality and storage stability of dried tomato, thereby reducing postharvest losses and improving its shelf life.

Keywords: Fluidized bed dryer, Tomatoes, Drying parameters, Postharvest loss, Proximate Analysis.

1 INTRODUCTION

In Nigeria, tomato accounts for about 18% of the average daily consumption of vegetables (Ibitoye *et al.,* 2009). The cultivation and production of tomato have been widely practiced due to its nutritional importance and medicinal value. Tomato is a good source of carbohydrate, protein, dietary fibre, calcium, magnesium, potassium, βcarotene, and lycopene (Hussein *et al*., 2018). Tomatoes are a good source of vitamin C, vitamin A and provide some vitamin E, folic acid, potassium and other trace elements. One of the benefits of tomato is its lycopene content. Lycopene is a vital anti-oxidant that helps in the fight against cancerous cell formation as well as other kinds of health complications and diseases. Diets that include tomato have been linked with reduced risk of obesity and some neurological diseases including Alzheimer's disease (Adegbola *et al.,*2019). Tomatoes and tomato based foods are considered healthy foods for several reasons. They are low in fat and calories, cholesterol free and a good source of fibre and protein (Shi, 2000) It is a seasonal and highly perishable vegetable, deteriorating few days after harvest which affect their nutritional and qualitative characteristics (Nakhasi *et al*., 2000). Tomatoes which are extremely valuable in nutritional qualities, especially ripe tomato is not suitable for long term storage after harvest. Due to high content of water (about 95%), tomato can deteriorate very quickly because of either chemical or microbiological effects. This situation leads to significant losses in terms of both nutritional and economic (Demiray and Tulek, 2008). The shelf life of tomato is within 4 to 6 days after harvest, and this is dependent on the variety and storage conditions. The short shelf-life of tomato, coupled with improper packaging and storage equipment, as well as lack of effective transport means has been one of the bottlenecks affecting the tomato industry (Idah *et al*., 2007). Tomato is one of the export crops in Nigeria, However, due to poor postharvest practices, Nigeria is unable to meet its domestic demands for tomatoes even though it ranks 13th on the world tomato production hierarchy. The high moisture content of tomato makes their handling, transportation and marketing a problem especially in the tropics. Tomatoes deteriorate rapidly after harvest, requiring preservation and/or processing in other to extend its shelf life. To extend the shelf life of tomatoes, they are processed into puree, ketchup, paste, powder, juice and canned whole. These processing methods preserve the nutritional qualities of fresh tomatoes although some may be lost during processing. The predominant method of preservation of fresh tomato in most homes is by storing at low temperatures. This however, often results in poor and uneven ripening, and in some instances, high fungal spoilage (Alam *et al*., 2009).

Dehydration is one of the most widely used methods for fruits and vegetables preservation. Drying tomatoes is one of the easiest known preservation methods. Tomato is a climacteric fruit, having a short shelf-life under ambient storage conditions. However, because of its shelf life, lack of proper processing, poor storage, poor packaging techniques and mechanical damages during harvesting, handling and transportation resulting from vibration by undulation and irregularities on the road there is sizable wastage and damage of it (Idah *et al*., 2007). In Nigeria, Farmers, marketers, and consumers encounter several challenges regarding the storage of the fresh tomato fruits. Such challenges which are the primary factors responsible for postharvest produce losses includes poor pre-harvest measures, biological and biochemical activities that occur in the fresh product, moisture condensation causing pathogen infestation, packaging in bulk without sorting and grading of produce, improper transportation, inefficient handling, unfavourable storage conditions and poor market outlet. These factors which affect the aftermath of tomato production result in losses which bring low return to the farmers (Kader, 2014). Hussein *et al.,* (2018) related that drying offers an effective way of preserving tomato. However, improper drying can lead to degradation of it colour, flavour, taste appearance and nutritional value and can accelerate some reactions that can adversely affect the product quality. Dehydrated tomatoes are concentrated in nutrients, but some of these nutrients may be lost during the process of drying. Extent of nutrient losses generally depends upon the material preparation prior to drying, the drying process and the storage conditions of dried products (Vinay, 2016). Even after drying, the food products are still susceptible to contamination and deterioration as a result of its contact with the environment, poor packaging material type and storage condition of the tomato product. Therefore, in order to improve the quality of the dried tomato product, a need for a safe drying method, packaging materials and storage conditions should be utilized to reduce quality losses during drying and storage.

2 MATERIALS AND METHOD

2.1 Materials

Good quality, fresh, ripe and matured tomato fruits was purchased from Engr. Kure Market Minna, Niger State, Nigeria, and transported to the crop processing and storage laboratory of the Department of Agricultural and Bioresources Engineering, Federal University of Technology, Minna, Niger State. The reagents and chemicals used for the various analyses were of quality analytical grades. The instruments and apparatus used for the study include the following: fluidized bed dryer, tarpaulins, cutting knives, boards, buckets, bowls, electronic weighing balance, mini hygrometer, oven, distilled water, muslin bags, conical flask, soxhlet apparatus, Kheldjal apparatus, measuring cylinder, filter paper, volumetric flask, heating mantle, burettes, petri dishes, desiccators, packaging materials (plastic container, glass container and polythene bag)

2.2 Methods

2.2.1 Experimental design

The study was conducted using a complete randomized block design with three drying factors (drying temperature, air flow velocity and thickness as depicted in Table 1) of fluidized bed dryer. The drying factors was optimized (consisting a total number of 17 runs as depicted in Table 2). After drying, the data collected were analysed statistically using box-behnken design of surface response methodology to determine the optimum proximate qualities for the fluidized bed dryer. The optimized sample was selected and reproduced to get suitable quantity for storage and packaged using three packaging materials. In a glass jar which is odorless, chemically inert, impermeable to gases and vapours, a low-density polyethylene bag and plastic jar with high barrier to water vapor, hot sealing, chemically resistant, inexpensive and lightweight. Then the proximate, microbial and sensory qualities of the stored dried tomato was analysed at an interval of one month during the storage period of five months at three replicates.

Table 1: Factors and levels used in the drying of experiments

Factors	Level 1	Level 2
	High	Low
Temperature(0C)	70	55
Hot air velocity(m/s)	1.2	0.8
Thickness (mm)	3	7

2.2.2 Sample preparation and drying

Fresh tomato was purchased from Engr. Kure market Minna, Niger state. The tomatoes samples were sorted, washed using sterilized water, drained and sliced into various thickness as shown in Figures 1 and 2. Some samples of the fresh tomato were collected and analyzed for its proximate qualities.

Figure 1: Tomato purchased from the vegetable market

Figure 2: Fresh tomato slices

Drying was conducted using fluidized bed dryer. Drying was conducted using fluidized bed dryer.

Fluidized bed drying: The sliced tomato was dried for each experimental layout as shown in Table 2 using a fluidized bed dryer (Figure 3). Three factors were varied at two levels each (Table 2). The drying was carried out until a water activity less than 0.6 was achieved, which was measured using a mini hygrometer shown in Figure 4.

Table 2: Experimental layout for the fluidized bed dryer

Run	Factors 1	Factor 2	Factor 3
	A: Temperature (□c)	Air Velocity(m/s)	Thickness(mm)
1	63	0.8	3
2	63	1	5
3	63	1	5
4	63	1.2	3
5	63	1	5
6	63	0.8	7
7	70	1	3
8	63	1	5
9	55	1.2	5
10	63	1	5
11	55	1	3
12	70	0.8	5
13	63	1.2	7
14	55	0.8	5
15	70	1.2	5
16	70	1	7
17	55	1	7

Study Type: Response Surface Methodology (completely randomized)

Design Type: Box-Behnken

Figure 3: Fluidized bed dryer

Figure 4: A Mini hygrometer

2.2.3 Sample drying, packaging and storage

After drying, the optimum sample for the drying was selected based on the factor that produced dried tomato with a maximum composition for protein, ash, crude fiber, fat, lycopene, β-carotene and minimum carbohydrate and moisture content. The computer software Design Expert 13.1.2.0 was used in making the selection, after inputting the proximate

composition result and the selection criteria. An overview of the dried tomato samples from the first experiment is shown in Figure 4.

Figure 5: An overview of the dried tomato samples from the first experiment

The selected optimized samples for the drying methods were reproduced to get suitable quantity for storage. The same variety of fresh tomato was bought from the market and prepared using the same procedure as in the first experiment and dried using the optimum conditions from the drying method. The dried samples were packaged into three sterilized packaging materials; plastic container, polythene bag and glass bottle as shown in Figure 6 and stored for a period of five months. The ambient temperature and relative humidity during storage were taken daily using a mini hygrometer and recorded. 80g of dried tomato were also left unpackaged as control, and stored for five months. The experimental layout for the packaging and storage of the dried tomato is shown in Table 3.4. Each sample were assessed and analyzed monthly to determine the proximate, β-carotene, lycopene, microbial and sensory qualities of the dried tomato.

Figure 6: Packaging of fluidized bed dried tomato using polythene, plastic and glass container

Table 3: Experimental layout for the packaging and storage of the dried tomato

S/N	Month	Factor 1: packaging type	Factor 2: Month
1	1	glass	1
2	1	plastic	1
3	1	polythene	1
4	2	glass	2
5	2	plastic	2
6	2	polythene	2
7	3	polythene	3
8	3	plastic	3
9	3	glass	3
10	4	glass	4
11	4	polythene	4
12	4	plastic	4
13	5	polythene	5

14	5	glass	5
15	5	plastic	5

2.3 Proximate analysis of the dried tomato

The proximate analyses of the fresh and dried tomato were determined according to the method described by the Association of Official Analytical Chemists (AOAC, 2018). The procedures for the determination of the proximate properties of the dried tomato are described as follows:

2.3.1 Determination of moisture content

The petri-dish was washed and dried in the oven for few seconds and removed, then cooled to room temperature in a desiccator. The petri dish was weighed using an electronic weighing balance and the corresponding weight was recorded as W_1. Five grams (5g) of the sample was measured and added to the petri-dishes, the weight of the petri-dish and the sample was recorded as W_2. The petri-dishes containing each sample were dried in an oven at 105^{0}C for 3 hours. The petri-dishes were transferred immediately to desiccators to cool and the new weight (W_3) was recorded. The moisture content present was calculated using Equations as follow:

$$\text{Moisture content (\%)} = \frac{\text{Loss in weight of the sample}}{\text{weight of the sample}} \text{ X } 100\% \quad (2.1)$$

$$\text{Moisture content (\%)} = \frac{W2-W3}{W2-W1} \text{ X } 100\% \quad (2.2)$$

Where:

W_1 = Weight of empty petri-dish

W_2 = Weight of petri-dish + initial sample

W_3 = Weight of petri-dish + dried sample

% Total solid (dry matter) = 100 - % Moisture content

2.3.2 Determination of Ash content

Ash content of the sample was estimated by using standard method (AOAC, 2018). Five gram (5g) of sample was weighed and transferred into a pre-weighed crucible. The sample was ignited with a Bunsen flame inside a fume cupboard until no charred particles remained in the crucible. The crucible was then placed in a muffle furnace (600^{o}C) for 3 hrs. The crucible was cooled in a desiccator and weighed to a constant weight. The difference between the weight of crucible with ash and as empty was amount of total ash.

$$\text{Ash (\%)} = \frac{\text{weight of the ash}}{\text{weight of the original sample}} \text{ X } 100 \quad (2.3)$$

2.3.3 Determination of Crude Fibre

Two grams (2g) of fat free dried sample was transferred into a beaker to which 200 ml of 1.25% sulphuric acid was added. The beaker along with contents was placed on hot plate and boiled for 30 minutes. After boiling, the content of the beaker was filtered through Whatman filter paper no. 4. The filter paper was transferred in a beaker containing 200 ml of 1.25% Sodium hydroxide. The contents weighed again was allowed to digest for 30 minutes and then filtered and washed again with hot water and alcohol thrice till free of alkali. The residue was then transferred in a pre-weighed silica crucible followed by drying in hot air oven at 100 ^{0}C. The crucibles were kept in muffle furnace and ignited for 30 minutes at 600 ± 15^{o}C followed by cooling and weighing. The loss in the weight after ignition represents the crude fibre (AOAC, 2018) and was calculated as follows.

$$\text{\% Crude Fibre} = \frac{\text{Weight of sample before ashing} - \text{Weight of sample after ashing}}{\text{Weight of sample}} \text{ x } 100 \quad (2.4)$$

2.3.4 Determination of Fat content

Two grams (2g) of the sample was placed in a 22 x 80 mm paper (serving as a thimble). A 250ml round bottom flask was weighed and then 150ml of petroleum ether, boiling point 60 – 80 ^{0}C was poured into the flask. The thimble was then placed in a glass tube which was fixed between the flask and a condenser connected to a Soxhlet extractor and refluxed for 16 hours on low heat application by heating mantle. The flask was then removed and evaporated on a steam bath. The flask containing the extracted fat was subjected to drying in a Gallen Kamp oven at 105 ^{0}C for 30 minutes, after which it was cooled to room temperature in a desiccator and then weighed (AOAC, 2018).

$$\% \text{ Fat} = \frac{W2-W1}{W3} \times 100 \quad (2.5)$$

Where: W_1 = Weight of empty flask ,W_2 = Weight of flask + fat ,W_3 = Weight of slices taken

2.3.5 Determination of Crude Protein content

Two grams (2g) of the sample was digested with 25ml conc. H_2SO_4 in a kjeldahl digestion flask in the presence of a catalyst (selenium) and anti-bumping agent until the mixture was clear. The clear, digested sample was transferred to a 100ml volumetric flask and made to the mark after cooling to room temperature. Distillation / condensation apparatus was set up and flushed with distilled water. 25ml of 2% boric acid was poured into a 250ml conical flask with two drops of mixed indicator (4ml of 0.1 % methyl red solution + 20ml of 0.1% in 95% alcohol bromocresol green solution) added to it and placed under the condenser with the tip of the condenser completely immersed in the boric acid solution.10ml of the digested sample solution and 20ml of 40% NaOH was transferred into the decomposition tube. Ammonia liberated during the distillation process was collected by the boric acid solution (for 5 minutes) turning it bluish green. The distillate was titrated with 0.1N HCl solution until the solution becomes colourless and then pink. The titre value obtained was used to calculate the nitrogen and hence the protein content.

$$\% \text{ Nitrogen} = \frac{Vs-Vb\ X\ Nacid\ X\ 0.01401\ X\ 100}{W} \quad (2.6)$$

Where, V_s = Volume of acid required to titrate sample (ml) V_b = Volume of acid required to titrate the blank (ml) N_{acid} = Molarity of acid, W = weight of sample (g)

$$\% \text{ Crude protein} = \%N \times \text{conversion factor} \quad (2.7)$$

$$\text{Where: Conversion factor} = \frac{100}{\%\ Nitrogen\ in\ protein}$$

Protein Conversion factor = 6.25

2.3.6 Determination of Carbohydrate

The carbohydrate content was calculated using the under-listed equation.

$$\text{Carbohydrate (\%)} = 100 - (\%P + \%F + \%A + M + \%C.F)\ \% \quad (2.8)$$

Where; P = Protein, F = Fat, A = Ash, M = Moisture, C.F = Crude fibre

2.4 Determination of lycopene and β-carotene

β-carotene and lycopene were determined following a procedure as outlined by (Charanjeet et al.,2004) measuring the absorbance at 453, 505, 645, and 663 nm. The contents were calculated according to the following equations:

β-carotene (mg/100 ml) = 0.216 × A663 – 1.220 × A645 - 0.304 × A505 + 0.452 × A453;

Lycopene (mg/100 ml) = – 0.0458 × A663 + 0.204 × A645 - 0.304 × A505 + 0.452 × A453 Where A663, A645, A505 and A453 refers to the absorbance at 663, 645, 505 and 453 nm, respectively. The values were expressed as (mg/100gm) of extract.

2.5 Sensory Evaluation of the dried tomato

Quantitative descriptive analysis was adopted for sensory attribute determination. Ten semi trained panelists who are familiar with dried tomato were selected at random from the Federal University of Technology, Minna. The quality attributes evaluated include: flavour, taste, appearance, texture, colour and overall acceptability of the dried tomato reconstituted to make soup. Similar to the method used by (Tsado 2015), the samples were evaluated on a grading scale 1 - 5: where 1-dislike very much; 2-dislike slightly; 3-Neither like nor dislike; 4-like slightly and 5-like very much).

2.6 Microbial examination

Total plate count (TPC) was determined based on the standard method using nutrient agar medium. Serially diluted sample (0.1g) of appropriate dilution was used for inoculation of medium in Petri plates followed by pouring of total plate count agar (10-15 ml) under sterilized conditions of laminar air flow. The plates were then incubated at 25 ± 2°C for 48 hours prior to counting. The results of total plate count (TPC) were expressed as log colony forming units (log cfu) of sample.

2.7 Data Analysis

All data collected were subjected to descriptive statistical analysis. The computer statistical software Design expert 13.1.2.0 and IBM SPSS statistics 26 was used to perform the analysis. The data were then compared using Duncan's multiple range test at 5% significant level.

3 RESULT AND DISCUSSION

3.1 Proximate Composition of Fresh Tomato

The results showed that the fresh tomato used for this study contains 93.1% moisture, 0.65% ash,0.58% protein, 0.93% crude fibre, 0.60% fat, and 4.14% carbohydrate. The proximate composition of the fresh tomato used for this study is similar to that reported for fresh tomato by Abdullahi *et al.,* (2016) and Hernandez *et al.,* (2008).

3.2 Effect of fluidized bed drying parameters and slice thickness on the proximate composition of dried tomato.

Table 4: The average proximate composition of the dried tomato using a fluidized bed dryer at two levels of temperature, air velocity and slice thickness

Runs	Drying Temperature °C	Air Velocity m/s	Slice Thickness mm	Moisture content %	Protein %	Carb. %	Ash Cont. %	Fat %	Crude fibre %
1	63	0.8	3	8.7	15.47	57.37	9.63	3.78	5.045
2	63	1	5	5.7	14.07	56.62	17.1	2.5	4.04
3	63	1	5	5.2	13.17	56.03	18.5	2.61	4.49
4	63	1.2	3	4.5	12.07	60.71	12.03	2.85	5.85
5	63	1	5	4.97	12.27	50.82	15.87	2.45	5.62
6	63	0.8	7	9.4	10.97	58.52	13.07	3.6	4.43
7	70	1	3	6.3	10.07	62.63	13.17	4.21	3.62
8	63	1	5	7.4	13.62	54.37	17.78	2.55	4.26
9	55	1.2	5	9.2	13.02	50.62	14.87	3.84	4.44
10	63	1	5	6.01	13.72	56	17.68	2.53	5.05
11	55	1	3	7.05	11.52	64.39	7.55	6.51	2.98
12	70	0.8	5	7.25	13.37	53.86	18.27	3.24	4.0
13	63	1.2	7	7.95	12.51	63.86	9.67	1.83	4.17
14	55	0.8	5	10.7	14.37	54.88	14.8	4.77	4.47
15	70	1.2	5	6.64	14.02	54.99	11.07	5.19	4.08
16	70	1	7	7.55	13.17	55.23	13	6.75	4.3
17	55	1	7	8.75	14.92	50.86	14.87	3.74	5.74

Table 5: Analysis of variance (ANOVA) of the effect of drying temperature, air velocity and slice thickness on the proximate composition of fluidized bed dried tomato

Source	**Sum of Squares df Mean Square F-value p-value**				
MOISTURE Model	40.05	9 4.45	4.18	0.0363	significant
A-Temperature	7.92	1 7.92	7.44	0.0295	
B-Hot Air Velocity	7.53	1 7.53	7.07	0.0325	
C-SLice Thickness	6.30	1 6.30	5.92	0.0453	
AB	0.1980	1 0.1980	0.1860	0.6793	
AC	0.0506	1 0.0506	0.0475	0.8336	
BC	1.89	1 1.89	1.78	0.2245	
Lack of Fit	3.81	3 1.27	1.39	0.3672	not significant
Cor Total	47.50	16			
PROTEIN Model	18.26	9 2.03	1.08	0.0468	significant
A-Temperature	0.064	1 0.064	0.0195	0.8630	
B-Hot Air Velocity	0.059	1 0.059	0.0318	0.2688	
C-Slice Thickness	2.70	1 2.70	1.44	0.9410	
AB	0.011	1 0.011	0.0059	0.1332	
AC	5.41	1 5.41	2.89	0.9942	
BC	3.42	1 3.42	1.83	0.2227	
Lack of Fit	6.34	3 2.11	1.25	0.4033	not significant
Cor Total	31.38	16			
CARBONHYDRATE Model 42.83		3 14.28	0.7401	0.05468 significant	
A-Temperature 4.45		1 4.45	0.2306	0.0391	
B-Hot Air Velocity 3.84		1 3.84	0.1989	0.6630	
C-SLice Thickness 34.55		1 34.55	1.79	0.2037	
Residual	**250.78**	**13 19.29**			
Lack of Fit	228.52	9 25.39	4.56	0.0789	not significant
Pure Error	22.26	4 5.57			
Cor Total	293.61	16			
ASH Model	160.79	9 17.87	8.22	0.0056	significant
A-Temperature	1.47	1 1.47	0.6747	0.0385	
B-Hot Air Velocity	8.25	1 8.25	3.80	0.0224	

C-SLice Thickness	8.51	1 8.51	3.91	0.0884	
AB	13.23	1 13.23	6.09	0.0430	
AC	14.06	1 14.06	6.47	0.0385	
BC	8.41	1 8.41	3.87	0.0899	
Residual	15.21	7 2.17			
Lack of Fit	11.34	3 3.78	3.90	0.1107	not significant
Pure Error	3.87	4 0.9682			
Cor Total	176.00	16			
FAT Model	30.21	9 3.36	11.86	0.0018	significant
A-Temperature	0.0338	1 0.0338	0.1195	0.7398	
B-Hot Air Velocity	0.3591	1 0.3591	1.27	0.2970	
C-SLice Thickness	0.2538	1 0.2538	0.8972	0.3751	
AB	2.07	1 2.07	7.33	0.0303	
AC	7.02	1 7.02	24.82	0.0016	
BC	0.1743	1 0.1743	0.6161	0.4582	
Lack of Fit	1.97	3 0.6554	186.20	0.0456	not significant
Cor Total	32.19	16			
CRUDE FIBRE Model	0.5535	3 0.1845	0.2792	0.0083	significant
A-Temperature	0.3403	1 0.3403	0.5151	0.057	
B-Hot Air Velocity C-Slice Thickness Lack of Fit Cor Total	0.0450 0.1682 6.96 9.14	1 0.0450 1 0.1682 9 0.7733 16	0.0681 0.2546 1.90	0.0482 0.0223 0.2808	not significant

The result of the statistical analysis of variance (ANOVA) of the data obtained from the first experiment (Table 4) indicated that the quadratic model is significant for moisture content, ash content, protein, crude fiber, carbohydrate, fat, β-carotene, and lycopene content. Also, the result shows that there was interaction effect between the temperature, hot air velocity and slice thickness of the fluidized bed dried tomato (Table 5)

3.2.1 Moisture

The moisture content of a food is very important factor on nutritional qualities and the shelf-life of that particular food. Drying is primarily done on food to reduce its moisture content thereby increasing the relative concentration of other food nutrient and hence improve shelf life. (Ukegbu and Okereke 2013). P-value less than 0.05 indicate model terms are significant. In this case A, B, C, are significant model terms. However, there were no significant model terms between the two-way interaction factor of AB, AC and BC (Table 4.1). There was significant difference in moisture content between control and dried tomato sample. The moisture content of the fresh tomato before drying was determined to be 93.1%. The maximum dry moisture content value (10.7%) was recorded in sample dried at 55^0C and minimum value (4.5%) was recorded in sample dried at 70^0C. The result indicates that as drying temperature, hot air velocity increases and slice thickness reduces the moisture contents of dried tomato decreased significantly (Table 3.0). This is attributed

to the evaporation rate which increased with increasing temperature. Gemede *et al.,* (2015) reported that the increase in temperature relative to the decreased moisture content is probably due to the lower drying rate at lower temperature. However, there was significant difference between the one factor interaction and no significant difference between the two-factor interaction. This result is in line with the report of Onuegbu *et al*., (2013), who stated that the dried samples were significantly different ($p \leq 0.05$) in moisture content from the fresh samples. According to Damodaran *et al*., (2008) water plays an essential role in the chemical and physical processes within foods. One of the importance of decreasing the moisture contents of product is that the microorganisms can no longer grow because many of the organisms found in the fresh material require a specific moisture content to grow.

3.2.2 Protein

P-values less than 0.0500 indicate model terms are significant. In this case A, B, C, are significant model terms (Table 5). The protein content in the dried tomato was lowest (6.01%) at 70^{o}C and highest (10.7%) at 55^{o}C (Table 4). There was significant difference between dried and control (fresh) samples regarding protein content. The protein content of the dried tomato was significantly affected ($p<0.05$) by the interaction of slice thickness, air velocity and temperature of drying. However, there was no significant model effect between the two-factor interaction of AB, AC and BC (Table 5). The result also indicates that decreasing of protein content is more in samples dried at high temperature than in sample dried at temperature. This shows that high temperature denatures the protein contents in dried tomato. This may be due to excessive heat which affect protein stability and causes molecules to vibrate rapidly and forcefully leading to the denaturation of the protein. In accordance with this, Idah and Obajemihi (2014) stated that as drying temperature increased from 50^{o}C to 70^{o}C, they observed protein contents of dried tomato decreased from 14.68 to 13.97%.

3.2.3 Carbohydrate

The carbohydrate content of dried tomato from this study ranges from 50.62% to 64.39%. The highest carbohydrate was recorded at 65^{o}c and lowest carbohydrate was recorded at 50^{o}C. This result indicated that the total carbohydrate content of dried tomato increases with temperatures, hot air velocity of drying (Table 5). The increase in carbohydrate content is likely due to change in moisture content during the drying process. Higher temperature and air velocities can increase the rate of moisture removal which may lead to a more rapid concentration of carbohydrates in tomato slices. Similar result was reported by Onuegbu *et al*., (2013) that lower value for carbohydrate content was observed in dried samples at lower temperature. This result also indicates that there was significant difference ($p<0.05$) between dried and control (fresh) samples regarding carbohydrate content. However, there was no significant difference ($p<0.05$) between interaction factor of B and C in carbohydrate contents of dried tomato (Table 5)

3.2.4 Ash Content

Ash is inorganic residue remaining after the water and organic matter have been removed by heating of a given food. It is a measure of the total amount of minerals present within a food. The results revealed that the ash contents of dried tomato fruit were affected significantly ($p \leq 0.05$) by interaction temperature and dried samples. There was also significant difference between the two-interaction factor of AB and AC but no model significant effect ($p>0.05$) between BC (Table 4). The maximum ash and minimum ash content were found as 18.27% in sample dried at 70°C and 7.55% at 50^{o}C which is higher than the fresh sample. The results showed that the ash content was high at low temperature. This implies that ash content decreases with increment of temperature (Table 5). It can also be seen from the results that there was more ash in dried tomato sample than control (fresh) tomato. This could be as a result of the removal of moisture which tends to increase the concentration of nutrients (Morris *et al*., 2004). The result was in line with findings of Onuegbu *et al*. (2013) who reported that the ash content of fresh tomato was lower than dried tomato samples. Similar to this, Idah *et al*. (2014) also reported that ash content decreases with increase in drying temperature because of denaturing of the samples at higher temperatures.

3.2.5 Fat

The results indicate that there was significant difference ($p<0.05$) in crude fat content between dried and control (fresh) tomato samples influenced by the significant interaction effects of slice thickness, air velocity and temperature of drying as the result illustrates in (Table 5). The value ranges between 1.73% and 3.75% . The result shows that as air velocity and temperature increase the fat content decreased. This could be attributed to the oxidation of fat at higher temperature. The lowering of fat in dried tomato contribute in reducing rancidity of product during storage and cholesterol level in the diet. However, there is significant difference ($p<0.05$) between interaction factor of AB and AC but no significant difference ($p>0.05$) between BC (Table 3.1). Results from this study are similar to finding of Famurewa and Raji (2011).

3.2.6 Crude fiber

The result revealed that the maximum (5.74%) and the minimum crude fiber content (2.98%) was found in the dried samples (Table 4). The crude fiber contents of the dried tomato decrease as temperature and air velocity increases. This

was as a result of high temperature and long duration which disrupt the cellular matrix of the products during drying process (Onifade *et al*., 2013). However, there was significant difference ($p<0.05$) between temperature and air velocity. This result is similar with the findings of Mozumder *et al*., (2012).

Table 6: The average composition of carotene content of the dried tomato using a fluidized bed dryer at two level of temperature, air velocity and slice thickness.

Runs	A: Temperature (°c)	B: Hot Air Velocity (m/s)	C: Slice Thickness (mm)	Lycopene %	β-carotene %
1	63	0.8	3	24.9678	8.87912
2	63	1	5	16.6659	7.69
3	63	1	5	17.4139	5.1914
4	63	1.2	3	16.0522	6.5601
5	63	1	5	16.8671	6.86885
6	63	0.8	7	15.056	6.58701
7	70	1	3	25.869	7.62105
8	63	1	5	17.0399	7.27192
9	55	1.2	5	12.1655	4.49327
10	63	1	5	17.1405	7.19399
11	55	1	3	22.8133	6.80272
12	70	0.8	5	22.1077	8.02509
13	63	1.2	7	14.2309	7.94009
14	55	0.8	5	13.8046	5.79337
15	70	1.2	5	24.3218	7.8848
16	70	1	7	17.5127	7.29198
17	55	1	7	8.67176	3.21954

Table 7: Analysis of variance (ANOVA) of the effect of drying temperature, air velocity and slice thickness on the carotene content of fluidized bed dried tomato

LYCOPENE Model 287.83		3 95.94		17.17	< 0.001 significant	
A-Temperature 130.86		1 130.86		23.42	0.0003	
B-Hot Air Velocity 10.50		1 10.50		1.88	0.00936	
C-SLice Thickness 146.47		1 146.47		26.22	0.0731	
Lack of Fit	72.31	9 8.03		100.84	0.0002	not significant
Pure Error	0.3187	4 0.0797				
Cor Total	360.47	16				
β-CAROTENE Model	27.26	9	3.03	4.26	0.0345	significant
A-Temperature	13.82	1	13.82	19.45	0.0031	
B-Hot Air Velocity 0.7238		1	0.7238	1.02	0.3464	
C-SLice Thickness 2.91		1	2.91	4.09	0.0827	

AB	0.3363	1	0.3363	0.4733	0.5136	
AC	2.65	1	2.65	3.73	0.0949	
BC	3.37	1	3.37	4.74	0.0658	
Lack of Fit	1.22	3	0.4068	0.4335	0.7409	not significant
Pure Error	3.75	4	0.9383			
Cor Total	32.23	16				

Source Sum of Squares df Mean Square F-value p-value

The result of the statistical analysis of variance (ANOVA) of the data obtained from the experiment indicated that the linear model is significant ($p<0.05$) for the lycopene content and the quadratic model is significant for β-carotene content.

3.2.7 Lycopene

The results showed that, lycopene contents ranged from 8.67 to 25.8 mg/100g in dried tomato samples. The lycopene content was significantly affected ($p<0.05$) by interaction of temperature and hot air velocity. This implies that lycopene content increases with temperatures of drying and air velocity (Table 7). This may be due to drying increasing the lycopene content by destructing the tomato cells and breaking the connection between lycopene and matrix, damaging the lycopene-protein complex and releasing free lycopene by *cis*-isomerization (high temperature enhance the extractability of lycopene from the tomato matrix). Dehghan *et al*., (2011) stated that when lycopene is extracted from its natural form, it bonds strong. Similar trend of lycopene contents in dried tomatoes has been reported by Abano *et al*. (2011). This implies that heating at higher temperature increases the lycopene pigment of dried tomato.

3.2.8 β-carotene content

The maximum β- carotene content was 8.88mg/100g and the minimum was 3.22mg/100g in dried sample. The findings depicted that there was continuous decrease of β-carotene with increasing of temperatures of drying. This could be attributed to the fact that β-carotene is more heat and air oxidation sensitive than lycopene. This implies that the bioactive substances of β-carotene are not thermos stable and are easily affected by heating (Regier *et al*., 2005). However, there was no statistically significant difference ($p<0.05$) between two factor interactions of AB, AC and BC. Similar findings were reported by Charles *et al*., (2014) who stated that there was a sharp decrease in β-carotene content of tomato samples as boiling or frying time increased and suggested that ß-carotene is a heat labile compound, and could be more available in raw tomato than the processed counterpart. Onuegbu *et al*., (2013) also found decreasing of β-carotene in tomato samples oven dried at 60^{o}C than fresh sample.

4 CONCLUSION

The following conclusion were made from the research; Temperature, air velocity and slice thickness had great effect at 5% level of significance on the proximate qualities and carotene content of dried tomato, the proximate qualities and carotene content of the fluidized bed dried tomato can be maximized by drying at temperature of 70^{o}C, air velocity of 0.9 m/s and slice thickness of 5mm. There was significant difference ($p<0.05$) between dried and fresh tomato. This may be due to thermal processing which occur during drying phase There was significant difference ($p<0.05$) between storage duration and stored sample. Storage study showed that there was slight decrease in protein, ash, crude fibre, lycopene, β-carotene, sensory qualities and increase in moisture content, carbohydrate, fat, bacteria and fungi count. The degradation rate was higher in the unpackaged dried sample and lower in glass jar and plastic jar compared to low density polyethylene.

STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

Disclosure of conflict of interest

The authors declare no conflicts of interest regarding this manuscript.

REFERENCES

[1] Abdullahi, G., Lin, B., Allshouse, J., & Kantor, L. (2016). Factors affecting tomato consumption in the United States. Economic Reasearch Service (Vegetables and Specialities), USDA, 282-293.

[2] Adegbola D, Olufunmilola A, Tari S, & Olaide A. (2019). Chemical and Microbiological Evaluation of Dried Tomato Slices. Global Journal of Nutrition and Food Sciences, 1(5):2019.

[3] Alam K., Ahmed M., Akter S., Islam N., & Eun J.B. (2009). Effect of carboxymethylcellulose and starch as thickening agents on the quality of tomato ketchup. Pakistan Journal of Nutrition, 30:428-433.

[4] AOAC. Official Methods of Analysis of the Association of Official Analytical Chemists. (2018). Tropical Vegetable production (19th ed.). (A. international, Ed.) Maryland, US: Macmillan Press Limted.UK.

[5] Charles, A.F.K., Loco, A.C., Zanatta, S., Spoto, M.H.F & Viera, M.F.S. (2014). Effect of temperature, time, and material thickness on the dehydartion process of tomato. International Journal of Food Science, 297-304.

[6] Dehghan, S.Z., Hardacre, A.K., Meerdink, G., & Brennan, C.S. (2011). Lycopene extraction from extruded products containing tomato skin. International Journal of Food Science and Technology, 46:365-371.

[7] Demiray D. and Turhan M. (2008). Thermal processing enhances the nutritional value of tomatoes by increasing total antioxidant activity. J.Agric.Food.Chem, 60(7):308-315.

[8] Famurewa, J.A.V and Raji, A.O. (2011). Physiochemical characteristics of osmotically dehydrated tomato under different common drying methods. International Journal of Applied Science and Technology, 5(3):1304-1309.

[9] Gemede, D.M., Nath, A., Deka, B.C & Mahanta, C.L. (2015). Thin layer drying of tomato slices. Journal of Food Science and Technology, 50:642-653.

[10] Hernandez, K.G.L.R., Kapilalarathne, R.A.N.S., Thilakarathne, B.M.K.S., Fernando,K.B., Palipane, M.D., & Prasana, P.H.P. (2008). Development of a methodology for production of dehydrated tomato powder and study the acceptability of the product. Journal of Agricultural Technology, 8(2):751-759.

[11] Hussein J. B., Ilesanmi J. O. Y., Filli K. B., & Sanusi M. S. (2018). Effects of Drying Methods on the Chemical Properties of Tomato Fruit (Lycopersiconlycopersium Mill) Slices. Journal of Applied Science and Technology, 26(6):1-10.

[12] Ibitoye D.O, Akin Idowu PE, & Ademoyegun O.T. (2009). Agonomic and lycopene evaluation in tomato (Lycopersiconlycopersium Mill.) as a function of genotype. World Journal of Agricultural Sciences, 5(5): 892-895.

[13] Idah P.A., Ajisegiri E.S.A., Yisa. M.O. (2007). Fruit and vegetables handling and transportation in Nigeria. Australian Journal of Technology, 10:175-183.

[14] Idah, P.A and Obajemihi, O.I. (2014). Effects of osmotic pre-drying treatments, duration and drying temperature on some nutritional values of tomato fruit. Academic Research Internatinal, 5(2).

[15] Kader, A.A. (2014). Post-harvest technology of horticultural crops. Second Edition. University of California, Division of Agricultiral and Natural Resources, 8:32-36.

[16] Morris, A., Barnett, A. and Burrows, O. (2004). Effect of processing on nutrient content of foods. Journal of Agronomy, 37:160-164.

[17] Mozumder, N.H.M.R., Rahman, M.A., Kamal, M.S., Mustafa, A.K.M & Rahman, M.S. (2012).

[18] Effects of pre-drying chemical treatments on quality of cabinet dried tomato powder. Journal of Environmental science and Natural Resources, 253-265.

[19] Nakhasi, S., Schlimme, D. and Solomos, T. (2000). Storage potential of tomatoes harvested at the breaker stage using modified atmosphere packaging. Journal of food science, 56:5559.

[20] Onifade, T.B., Aregbesola, M.T.I & Ajayi, A.O. (2013). Some physical properties and thin layer drying characteristics of local varieties of tomatoes. Journal of Agricultural Biology, 4(3):275-279.

[21] Onuegbu, N.C., Kalu, H., Ihediohanma, N.C., & Bede, N.E. (2013). Effect of different pretreatment on the nutritional and sensory qualities of tomato (Lycopersicum esculantum) powder. International Journal of Life Sciences, 2(3):121-123.

[22] Regier, E., Mayer-Miebach, D., Behsnilian, E., & Neff, H.P.S. (2005). Influence of drying and storage of lycopene and storage of lycopene-rich carrots on the carotenoid content . Drying Technology, 23(4):989-998.

[23] Shi J.X. (2000). Lycopene degradation and isomerisation in tomato dehydration. Food Research International, 32(1):15-21.

[24] Ukegbu, P.O and Okereke, C.J. (2013). Effect of solar and sun drying methods on the nutrient composition and microbial load in selected vegetables, African spinach (Amaranthus hybridus), Fluted pumpkin (Telferia occidentalis) and okra (Hibiscus esculentus). Sky Journal of Food Science, 2(5):35-40.

[25] Vinay, V. (2016). Impact of drying methods on the quality attributes of tomato fruit (Lycopersicon lycopersium Mill). Kashmir University of Agricultural Sciences and Technology of jammu, 4:167-171.