MODELING AND OPTIMIZATION OF PROCESS CONDITIONS AND SOME NUTRITIONAL QUALITIES OF DRIED TOMATO USING RESPONSE SURFACE METHODOLOGY

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ABSTRACT

Tomato fruits are seasonal and highly perishable due to high moisture content, thereby making the preservation difficult. Drying is one of the ways to preserve the nutritive qualities of the product. In this research, optimum temperature and time necessary for drying tomatoes using a response surface approach were studied. Central Composite Rotatable Design (2 × 5) was adopted. Drying temperatures and time selected were 50, 55, 60, 65 and 70 °C; 16, 17, 18, 19 and 20 hr, respectively. The protein, fat, ash, carbohydrate and fibre contents as well as the calorific values of the dried tomatoes were determined. Four different models were used to analyze the nutritional qualities of the dried tomatoes and the models were fitted to the experimental data using Design Expert Software. Data analyses were done using multiple linear regression at p = 0.05. Predicted optimum conditions were validated using experimental values. It was observed that drying temperature and time affected the nutritional qualities of the samples. Protein content ranged from 0.70-6.48%, fat content ranged from 2.50-9.50, ash content ranged from 9-17%, carbohydrate content ranged from 68.12-81.22, fibre content ranged from 0.50-1.50 and the calorific value ranged from 348.50-397.00 kCal. The predicted optimal values were 5.68% protein content, 7.62% fat content, 15.47% ash content, 72.61% carbohydrate content, 0.92 fibre content and 370.30 kCal calorific value at drying temperature of 55 °C and drying time of 17 hrs with a desirability of 0.56. Under these optimal conditions, the experimental values were 5.36% of protein content, 7.50% fat content, 15.00% ash content, 71.14% carbohydrate content, 1.00% fibre content and 333.50 kCal calorific value. The deviations between experimental and predicted values were low and statistically insignificant which implies that the various models selected could actually predict the nutritional qualities of the dried tomatoes.

KEYWORDS: Tomatoes, preservation, drying, temperature, time, quality

1. INTRODUCTION

Tomato is one of the most important vegetable crops grown all over West Africa, and Nigeria in particular (Showemimo *et al.,* 2006). Like other vegetables, tomato is a very important source of nutrients for human consumption (FORA, 2014). Tomato is rich in nutritional and functional composition such as lycopene, carotenoid compound (80-90%) and β-carotene, which have anti-cancer and anti-oxidative properties (Ali *et al.*, 2020; Gerszberg *et al.*, 2015). Lycopene, carotenoid compound and β-carotene encourage increasing interest in tomato. However, it is a highly perishable commodity due to its high moisture content [about 80% wet basis] (Al-Maiman *et al.,* 2021). As a result, tomato is susceptible to spoilage few days after harvesting, even at

refrigerated conditions, resulting in reduced product quality and total wastage in most cases (Arepally *et al.,* 2017). Thus, alternative and appropriate handling technology in the tomato postharvest supply and storage management chain becomes indispensable.

In recent years, several technologies have been employed to help reduce the postharvest losses of fruits and vegetables, which is about 30-40% in developing countries (Karim and Hawlader, 2005). In fact, over 50% of these losses occur in the postharvest storage value chain (Orsat *et al.,* 2006). These preservation methods include drying, heating, hydro-cooling, sterilization and so on. However, the most commonly used method is drying.

The production of agricultural products such as fruits and vegetables are seasonal in Nigeria. There are periods when there is a glut and at other times, when there is acute shortage. The obvious acute shortage of agricultural products at some periods of the year is attributed to poor storage facilities (Scheepens *et al.,* 2011). The immediate effect of poor storage facilities was the evasion of farming benefits due to anticipated losses such as reduction in sales and crop deterioration. To reduce this wastage, there is need to process fresh tomato into powder which can last for a longer time and enhance diversity which can also balance the seasonal cost/availability of the vegetable.

Drying is one of the oldest methods of preserving food products. This preservation method requires less energy consumption compared to freezing, sterilizing and hydro cooling (Onwude *et al.,* 2016). Drying involves the removal of moisture from a material due to simultaneous heat and mass transport within the product (Onwude *et al.,* 2016). Recent studies have discussed on the drying of fruits and vegetables using different types of drying methods including sun drying (Gupta *et al.,* 2017), solar drying (Alonge & Onwude, 2013), convective hot-air drying (Ratti, 2001), freeze drying (Ratti, 2001), infrared drying (Onwude *et al.,* 2018), vacuum drying (Nadi *et al.,* 2012), microwave drying (Feng *et al.,* 2012), electrohydrodynamic drying (Defraeye & Martynenko, 2018) and combined-modes drying (Hebbar *et al.,* 2004). However, the conventional hot-air drying method is still widely used owing to its design simplicity and affordability.

However, the concept of drying to powder to mitigate the above challenges is not without some major problems such as ensuring maximum retention of nutrients after drying and choosing a drying method that will keep the powdered tomato within the purchasing power of most Nigerians, hence the need for this research work. Several researches have been carried out with regards to the drying of tomato (Gaware *et al.,* 2010). However, from the researches available on tomato drying, there is no known random selection of process parameters that would have given effective and quality dried tomato slices. Besides, studies on developing mathematical models explaining the drying conditions and nutritional properties of dried tomato slices have not been carried out. Therefore, this work investigated the effects of tomato processing variables on its proximate composition, where models were developed to relate the processing variables and the nutritional qualities.

2. MATERIALS AND METHODS

2.1 Sample Preparation

The garden tomato (*Solanum lycopersicum* L.) used for this work was purchased from Akpan Andem Market in Uyo, Akwa Ibom State and classified in the Department of Crop Science, University of Uyo. From the bulk tomato samples, the moderately soft ripened (90% of the bulk) and firm ripened tomatoes (10% of the bulk samples) were selected and washed in clean water. Proximate analysis was carried out on some quantities of tomato to serve as control. Exactly 0.5 kg of tomato was sliced using a sharp stainless-steel kitchen knife into thin layer of 0.5 cm thickness and placed in a dehydrator before each drying experiment. The drying test was conducted at five different temperatures (50, 55, 60, 65 and 70^{o}C) and drying times (16, 17, 18, 19 and 20 hrs) using Presto 06301 De-hydro Digital Electric Food dehydrator. At the end of each experiment, the dried products were left to cool for 5 minutes, blended and taken for proximate analysis. The experiment was carried out in triplicate for each drying temperature and time and is shown in Figures 1 and 2.

Figure 1: Sliced tomato samples in a dehydrator before dying

Figure 2: Sliced tomato sample in a dehydrator after dying

2.2 Experimental Design

The effects of the drying temperature and drying time on the moisture, protein, fat, ash, carbohydrate and fibre contents of powdered tomato were investigated. The experimental design adopted was 2 factors, 5 levels, factorial Central Composite Rotatable Design (CCRD) of Response Surface Methodology (Box *et al.*, 1978). Central Composite Rotatable Design is comprised of three types of design points namely factorial points (n_f), axial points (n_a) and central points (n_c). According to the Central Composite Rotatable Design, the total number of treatment combinations is $n = 2^k (n_f) + 2k(n_a) + k(n_c)$ where 'k' is the number of independent variables and n is the number of repetition of experiments at the center point. The total number of design points is thus $N = 2^k + 2k + n_o$ (Fakayode and Ajav, 2016; Umani *et al.*, 2019; Ikrang and Umani, 2019). Therefore, the CCRD involved 13 experiments consisting of 2^2 factorial CCD, with 4 axial points ($\alpha = 2$) and 5 replications at the center points (Table 1). For each independent variable, the levels were chosen with respect to preliminary experiments, observations and previous reports by other researchers. Five drying temperatures (50, 55, 60, 65 and 70^{o}C) and heating times of (16, 17, 18, 19 and 20 hours) were chosen. Coded values of the independent variables (-2, -1, 0, 1, 2) was used; where -2, 0 and 2 represent the lowest, medium and highest levels respectively.

2.3 Determination of Protein Content

The protein content was determined using the Kjeldahl method according to Chang (2003). About 0.15 - 0.28 g of the sample was weighed and transferred to a Kjeldahl flask. Exactly 3-4 g of the catalyst mixture (1.5 -2.0 g anhydrous Na_2SO_4, 1.5-2.0 g $CuSO_4$, 10 ml H_2SO_4) was then be added to the flask and heated gently. When the initial frothing had ceased, a loose peat stopper was fixed on the top of the flask and the temperature increased. The flask was shaken thoroughly at different time intervals while the heating process continued for 1 hr until a clear liquid was formed. The digest was cooled and washed into a 100 ml volumetric flask with distilled water and diluted until the volume reached 100 ml.

Table 1: Experimental Design (Second Order Design in the Two Variables)

Runs	X_1	X_2	Temperature (°C)	Time (min.)
	Coded Values		Actual Values	
1	1.000	1.000	65	19
2	0.000	0.000	60	18
3	1.000	-1.000	65	17
4	0.000	0.000	60	18
5	0.000	0.000	60	18
6	-1.000	-1.000	55	17
7	0.000	0.000	60	18
8	-2.000	0.000	50	18
9	0.000	-2.000	60	16
10	0.000	0.000	60	18
11	0.000	2.000	60	20
12	-1.000	1.000	55	19
13	2.000	0.000	70	18

50 – 70 represent Temperature levels 1, 2, 3, 4 and 5 respectively;
16 – 20 represent drying time levels 1, 2, 3, 4 and 5 respectively.

The digest was then poured into a distilling flask and connected to the condenser to ensure circulating of cooling water. To the receiving conical flask, 25 ml of 2% boric acid solution and 2 drops of combined indicator (2:1; methyl red: methyl blue in alcohol) was added. The diluted digest alkaline was made with 40% NaOH solution (at least 40 ml was added). The distillation apparatus is connected with the delivery tube dipping below the boric acid solution and the ammonia is distilled into the boric acid solution. After about 4 minutes or 30 ml has distilled over, the condenser and delivery tube were washed into the receiver. About 0.1 N HCl was titrated with the distillate to its end (purplish grey colour). The blank should not exceed 0.5 ml. The percentage nitrogen was calculated using Equation 1.

$$\%\ Nitrogen\ content = \frac{0.14 \times A}{weight\ of\ food\ sample\ (g)} \quad (1)$$

Note: 1 ml 0.1 N HCl = 0.0014 gN
where A = titre value

Using Equation 2, % crude protein was calculated with an appropriate factor (the general factor is 6.25). Thus,

$$\%\ Protein\ content = \frac{0.14 \times A \times 6.25}{Weight\ of\ food\ sample\ (g)} \quad (2)$$

where A = titre value

2.4 Determination of Fat Content

To determine the fat content, the Soxhlet extraction with petroleum ether (40 - 60ºC) was used according to Chavan (2012). The bottom flask was cleaned by washing using running water and then placed in an oven to dry at 105ºC, before cooling using desiccator. The clean bottom flask was then weighed. Approximately 2 grams of the product was then weighed and used. The thimble was dried in an oven, cooled and weighed. The weighed 2 g of sample was then added into the thimble and weighed, while the mouth of the thimble was plugged lightly with cotton wool and weighed. The thimble was placed in the extractor and then the addition of solvent until siphons. After which more solvent addition was done till the extractor's barrel was half full, before replacing the condenser. The joints were tightened while cooling water was circulated. The round bottom flask was heated using a heating mantle and was adjusted so that solvent boiled gently and left to siphon over for 4 hours. When the ether just siphoned over the extractor's barrel was empty, the condenser was removed, and thereafter the thimble was removed. The condenser was then replaced and allowed to siphon once more. The solvent was evaporated from the miscella (oil + solvent) in the round bottom flask by placing the flask in a water bath, cooled and then recording the weight. The percentage fat content was estimated based on Equations 3:

$$\%\ Lipid\ or\ fat = \frac{W_2 - W_1}{\mathrm{b-a}} \times 100 \quad (3)$$

where: W_1 = weight of bottom flask (g), W_2 = weight of bottom flask and its content (g), a = weight of thimble (g) and b= weight of thimble and sample (g)

2.5 Determination of Ash Content

The ash content of the sample was determined according to the method adopted by Chinyere *et al.* (2014). All crucibles were washed and ignited in the muffle furnace. The crucibles were removed from the furnace, cooled in the desiccator for 10 minutes, labelled, weighed and recorded. About 3 - 5 g of the sample was added to each crucible and the weight recorded. The sample was incinerated in the muffle furnace at a temperature of 550ºC until it was completely turned grey in colour. It was removed, cooled in a desiccator for 10 minutes and the weight recorded. The ash content was calculated using Equation 4.

$$\%Ash\ Content = \frac{W_3 - W_1}{W_2 - W_1} \times 100 \quad (4)$$

where, W_1 = weight of empty crucible (g),
W_2 = weight of crucible + sample before incineration (g) and
W_3 = weight of crucible + ash (g).

2.6 Determination of Carbohydrate

The determination of carbohydrate was carried out using difference method (Ranganna, 2001), by finding the difference between 100% and the percentage summation of ash, fat, protein and crude fibre contents.

2.7 Determination of Fibre Content

The fibre content was determined using AOAC method (1990) as adopted by Jannot *et al.,* (2004). Two grams of the sample was defatted with petroleum ether for 2 hours after which it was boiled under reflux for 30 minutes with 200 ml of a solution containing 125% of H_2SO_4 per 100 ml solution. After boiling it was filtered through a cotton cloth on a fluted funnel and washed with boiling water until the washing was no longer acidic. The residue was transferred to a beaker and boiled for 30 minutes with 200 ml of a solution containing 1.25g of NaOH per 100ml. the final residue was filtered and washed with boiling water several times until it is base free. The residue was finally washed twice with ethanol and qualitatively transferred into a pre-weight crucible (I_o), oven dried at 105^{o}C and incinerated in a furnace at 55^{o}C, allowed to cool and weighed (I_a). The percentage crude fibre was calculated using Equation 5:

$$\% \, Crude \, fibre = \frac{I_a - I_o}{weight \, of \, sample} \quad (5)$$

where:

I_o= weight of sample (g)
I_a= Weight of dry residue (g)

2.8 Determination of Caloric Value (Energy)

The caloric values of the sample were obtained by multiplying the value of the crude protein, lipid and carbohydrate by 4, 9, 4 kCal respectively and taking the sum of the products (Ranganna, 2001).

2.9 Response Surface Methodology (RSM) and statistical analysis

The optimization of drying parameters was done using the response surface methodology (RSM). For the design of experiments, analysis and modeling, Design Expert (version 6.0.6) software package was used. Data obtained through the experimental matrix was computed for the determination of regression coefficient of the second Order multiple regression models. The analysis of regression and variance was also performed by the Design Expert. The model and parameter validations were done by repeating the experiments at optimal conditions (Islau *et al.*, 2002). The results obtained were then compared with the predicted results. Analysis of variance (ANOVA) was used to explain the model fit quality. The significance of the model's individual term and the interactions with responses were also observed using ANOVA, based on 5% level of significance and regression coefficient.

3. RESULTS AND DISCUSSION

3.1 Design Summary

The average summary of the proximate analyses is presented in Table 2, while the design summary is presented in Table 3. From the range of values studied as presented in Table 2, increase in the drying temperature from 50-60^{o}C at drying time of 18 min., decreased the protein, fat, ash, carbohydrate, fibre and calorific content of the dried tomato samples by 6.92, 52.63, 11.76, 7.62, 66.67 and 5.56% respectively, while increase in the drying temperature from 50-70^{o}C at drying time of 18 min., decreased the protein, fat, ash, carbohydrate, fibre and calorific content of the dried tomato samples by 76.35, 31.35, 13.32, 0.06 and 1.85% respectively.

Table 2: Proximate Analyses of Dried Tomatoes at various Processing Conditions

Runs	Temperature (°C)	Time (hr)	Protein (%)	Fat (%)	Ash (%)	Carbohydrate (%)	Fibre (%)	Caloric Value (kCal)
1	50	18	2.96	9.50	17.00	70.04	0.50	377.50
2	55	19	2.63	2.50	15.00	79.37	0.50	350.50
3	55	17	6.48	8.00	16.00	68.52	1.00	372.00
4	60	18	3.31	4.50	17.00	73.69	1.50	348.50
5	60	18	3.50	4.00	16.00	75.00	1.50	350.00
6	60	18	3.23	4.00	16.00	75.27	1.50	350.00
7	60	18	3.15	4.50	16.00	74.85	1.50	352.50
8	60	16	4.38	3.50	12.50	79.12	0.50	356.36
9	60	18	3.18	4.50	15.00	75.82	1.50	356.50
10	60	20	2.98	7.50	12.00	77.02	0.50	387.50
11	65	17	0.70	4.00	14.00	79.80	1.50	358.00
12	65	19	2.28	7.00	9.00	81.22	0.50	397.00
13	70	18	0.70	6.50	11.50	80.80	0.50	384.50

Table 3: Design Summary

Response	Name	Observation	Minimum	Maximum	Trans	Model
Y1	Protein	13	0.70	6.48	None	Quadratic
Y2	Ash	13	9.00	17.00	None	Quadratic
Y3	Fibre	13	0.50	1.50	None	Quadratic
Y4	Fat	13	2.50	9.50	None	Quadratic
Y5	Carbohydrate	13	68.52	81.22	None	Linear
Y6	Caloric Value	13	348.50	397.00	None	Quadratic

Note: Study Type: Response Surface : Experiments: 13
Initial Design: Central Composite Blocks No Blocks

3.2 Effects of Processing Factors on Protein Content

The protein content of the dehydrated samples increased steadily at lower temperatures and times (50ºC for 18 hours, 55ºC for 17 hours, 60ºC for 16 hours) and decreased at higher temperatures and time (60ºC for 20 hours, 65ºC for 17 hours, 70ºC for 18 hours), showing dehydration at higher temperature and time causes the denaturing of the protein due to the breakdown of molecules of amino acid (Figure 3). The protein content of the control sample was significantly different from that of the dehydrated samples except those dried at 65ºC for 17 hours and 70ºC for 18 hours, both yielding 0.7% protein content as to 1.05% in the control. The increase in protein as seen in other samples is as a result of higher concentration of the sample due to removal of the moisture content and is in line with a similar works reported by several researchers (Abulude *et al.*, 2007; Abiodun and Adeleke 2010; Onimisi and Ovansa, 2015; Abdullahi *et al.*, 2016)

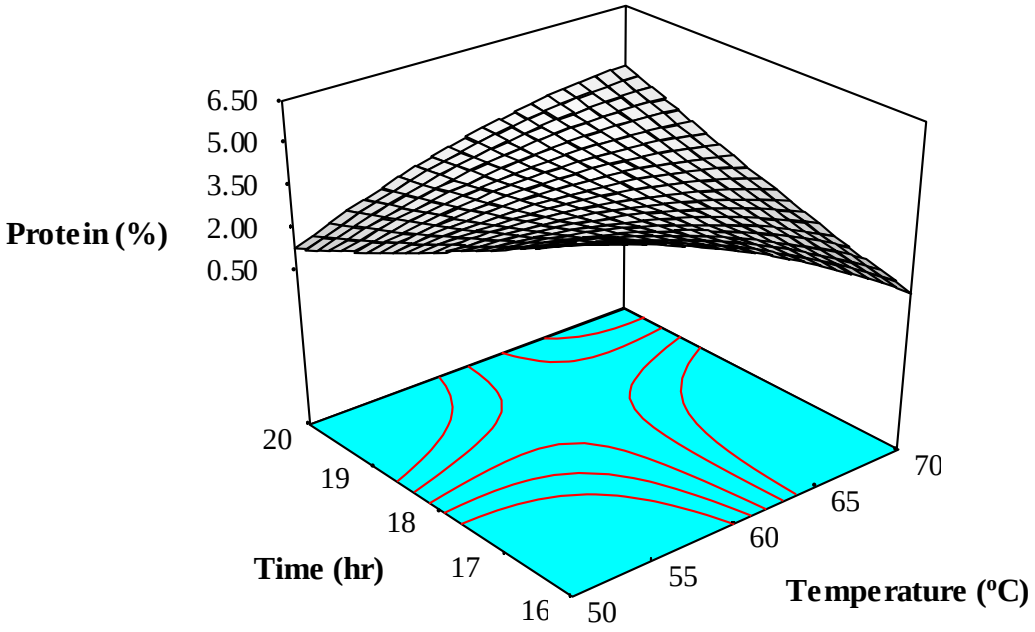

Figure 3: Response Surface for Protein Content as Affected by Drying Temperature and Time

3.3 Effects of Processing Factors on Fat Content

With regards to fat content, drying tomato at 50ºC for 18 hours resulted in the highest fat value and as temperature increased with time the fat content decreased due to high temperature denaturing the fat (Figure 4). Though the fat content of the dehydrated samples was higher than the raw sample. The difference may be due to that more grey matter were brought together than in the raw sample which contained a high volume of moisture.

3.4 Effects of Processing Factors on Ash Content

This study revealed that the interaction between drying temperature and time greatly affected the ash content. The maximum ash content found at 60ºC for 18 hours and 50ºC for 18 hours both yielding 17% ash content, which is higher than the control with yield of 16.5% (Figure 5). The result showed a rise in ash content at low temperatures, and a reduction in ash content with increased drying temperature and time. This could be as a result of the removal of moisture which tends to increase the concentration of nutrients (Yusufe *et al.*, 2017).

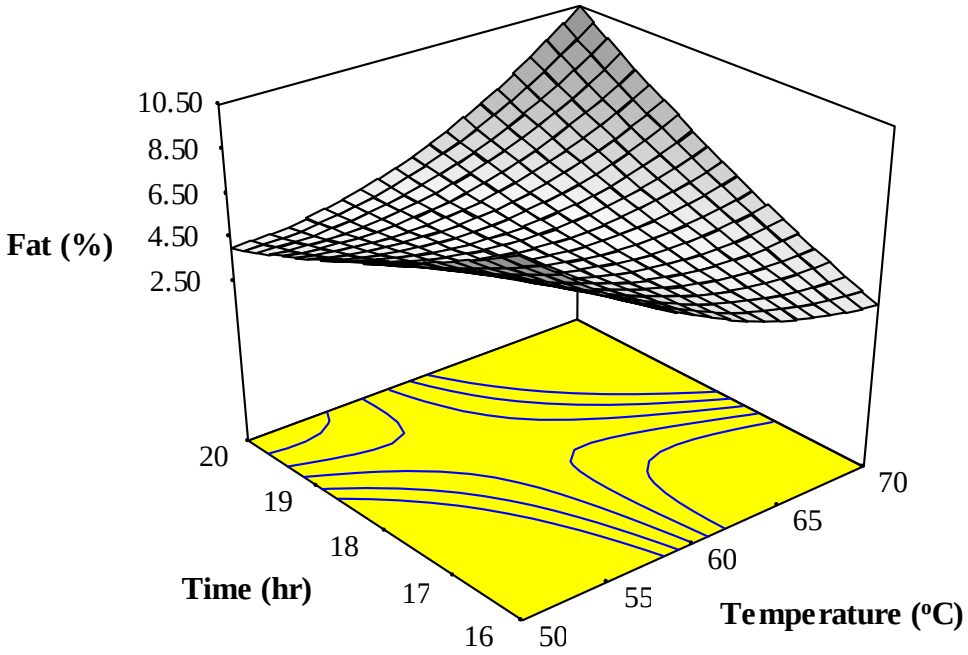

Figure 4: Response Surface for Fat Content as Affected by Drying Temperature and Time

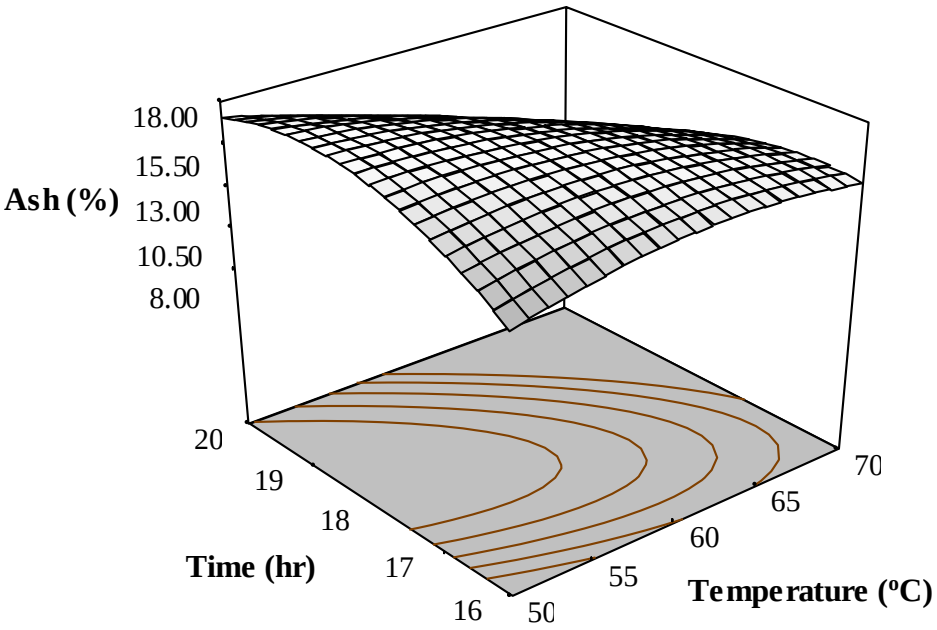

Figure 5: Response Surface for Ash Content as Affected by Drying Temperature and Time

3.5 Effects of Processing Factors on Carbohydrate content

From the results, tomato dehydrated at 65ºC showed the highest level of carbohydrate (81.22%) than the control sample (79.75%) with decrease in its level with temperature as seen in 55ºC (68.52%). The result indicates that the total carbohydrate content of the dried tomato increased with temperature and time (Figure 6). This is expected because the carbohydrate content was obtained by differences in other nutrients which was degraded by increase in temperature and time. Similar result was obtained by Yusufe *et al.* (2017) who reported that lower carbohydrate content (8.44%) in the control and 60.15% in samples dried at 90ºC for 8 hours and also conformed with the observation of Onuegbu *et al.* (2013) who reported lower carbohydrate content (0.43%) in the control sample than samples dried at 60ºC.

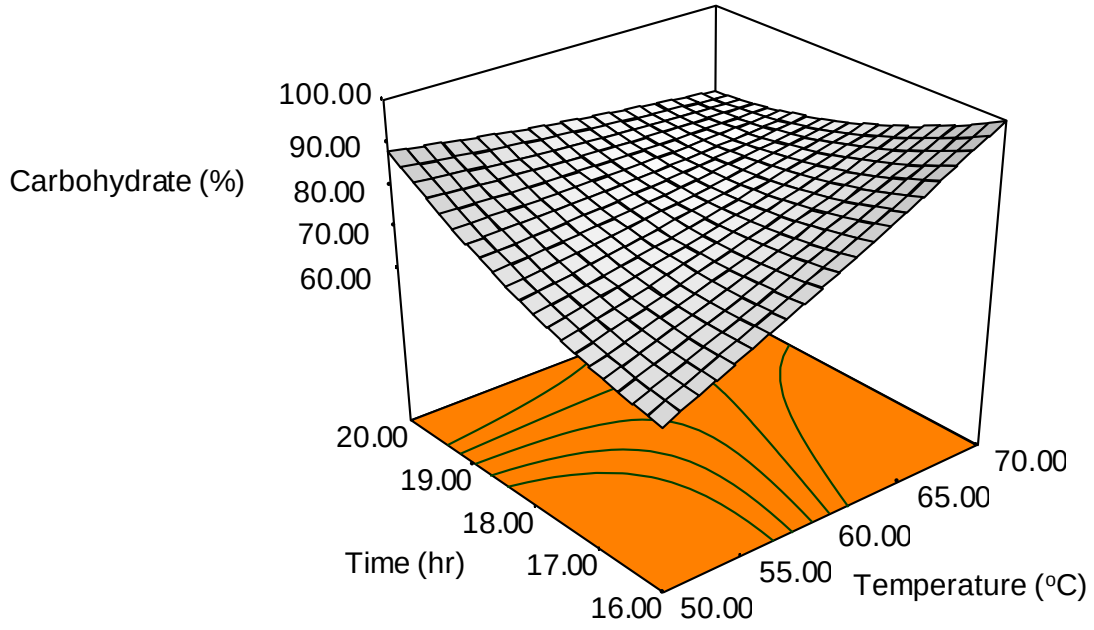

Figure 6: Response Surface for Carbohydrate Content as Affected by Drying Temperature and Time

3.6 Effects of Processing Factors on Fibre Content

The results of this study demonstrated that drying temperature and time affected the fibre content of tomato. The results further revealed that the maximum crude fibre (1.5%) are seen at drying temperature 60ºC for 18 hours which are higher than the control due to its high moisture content contributing to the low dry matter containing the crude fibre (Abdullahi *et al.*, 2016) and minimum crude fibre content (0.5%) at temperatures and time above 60ºC for 18 hours (Figure 7). The crude fibre contents of the dehydrated tomato decreases as duration and temperature increases due to the disruption of the cellular matrix of the product (Abulude *et al.*, 2001; Abiodun and Adeleke, 2010; Onifade *et al.*, 2013; Ikrang and Umani, 2019).

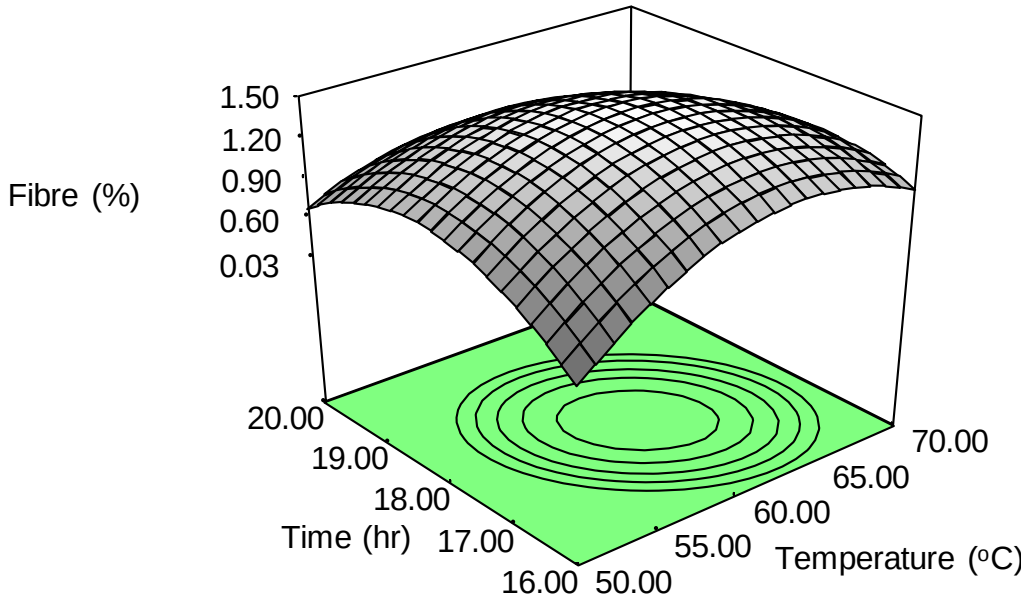

Figure 7: Response Surface for Fibre Content as Affected by Drying Temperature and Time

3.7 Effects of Processing Factors on Caloric Value

The caloric value was seen to increase from the lowest temperature 50ºC dried for 18 hours to a maximum caloric value (397 kCal) at 65ºC for19 hours and started to decrease with increase in temperature and drying time (Figure 8). This is because the estimation of the caloric value was determined by multiplying the crude protein, lipid and carbohydrate by factors 4, 9, and 4 respectively.

3.8 Predictive Models for the Nutritional Qualities

The nutritional qualities of dried tomatoes including fat, carbohydrate, protein, fibre, and ash contents, coupled with caloric values were analyzed using 4 different models (linear, two factorial interaction (2FI), quadratic, and cubic) (Table 4). The experimental drying data were fitted to the selected model using Design Expert software. Statistical tools of adjusted and predicted R-squared values were used to select the best model. The model with the highest order polynomial based on the "Adjusted R-squared", and "Predicted R-squared" values gave the best results (Fakayode and Ajav, 2016; Umani *et al.*, 2019). Considering these, the quadratic model was chosen for the protein content, fat content, ash content, fibre content and calorific value, while the linear model was selected for the carbohydrate content.

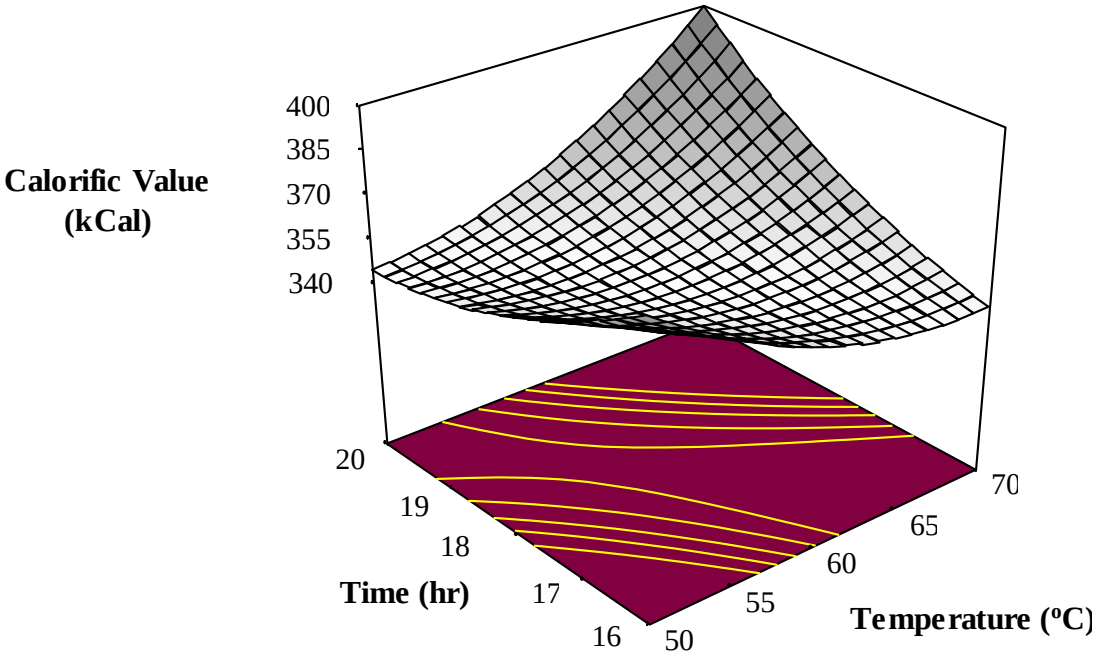

Figure 8: Response Surface for Caloric Value as Affected by Drying Temperature and Time

Table 4: Model Selection for the Proximate Analyses

Response	P_r (%)	F_t (%)	A_s (%)	C_d (%)	F_b (%)	C_v (kcal)
Model	Quadratic	Quadratic	Quadratic	Linear	Quadratic	Quadratic
Std. Dev.	0.62	1.16	1.29	2.84	0.26	6.08
R^2	0.89	0.82	0.84	0.57	0.85	0.92
Mean	3.04	5.38	14.38	76.19	1.00	364.68
Adjusted R^2	0.82	0.69	0.72	0.48	0.74	0.87
C.V.	20.45	21.57	8.94	3.73	25.63	1.67
Predicted R^2	-0.04	-0.79	-0.24	0.15	-0.51	0.40
PRESS	26.81	93.34	88.65	157.40	4.54	2023.57
Adeq. Precision	13.33	8.15	7.25	8.47	7.23	10.54

Std. Dev. = Standard deviation, C.V. = Coefficient of Variation, PRESS = Predicted Sum of Square, Adeq. Precision = Adequate Precision, P_r = Protein Content, F_t = Fat Content, A_s = Ash Content, C_d = Carbohydrate Content, F_b = Fibre Content, C_v = Calorific Value

The final equations for the fat, carbohydrate, protein, fibre, and ash contents, and calorific value are given in Equation 6, 7, 8, 9, 10 and 11:

$$Protein\ Content = 295.72 - 3.33T - 20.37t - 0.01T^2 + 0.10t^2 + 0.27Tt \quad (6)$$

$$\text{Fat Content} = 698.70 - 12.17\text{T} - 35.75\text{t} + 0.04\text{T}^2 + 0.30\text{t}^2 + 0.43\text{Tt} \quad (7)$$

$$\text{Ash Content} = -546.64 + 5.48\text{T} + 45.86\text{t} - 0.02\text{T}^2 - 0.96\text{t}^2 - 0.20\text{Tt} \quad (8)$$

$$\text{Carbohydrate Content} = 29.44 + 0.58T + 0.67t \quad (9)$$

$$\text{Fibre Content} = -141.79 + 1.67T + 10.45t - 0.01T^2 - 0.25t^2 - 0.03Tt \quad (10)$$

$$\text{Caloric Value} = 6214.16 - 89.52T - 362.07t + 0.30T^2 + 5.20t^2 + 3.03Tt \quad (11)$$

Where, T = Drying temperature, ^oC; t = Drying time, hr

The positive terms in the equation represent a direct relationship between processing factors and interactions with nutritional qualities, while the negative terms represent an inverse relationship between them. It was observed that drying temperature and time have effects on nutritional qualities.

From the ANOVA for the selected response surface models for the nutritional contents of the dried tomato sample the model p-values for protein, fat, ash, carbohydrate, fibre and calorific content are less than the chosen significance level of 0.05 (Table 5), with satisfactory coefficients of determination R^2 (Table 4), this implies that the selected models are adequate to predict the nutritional contents of the dried tomato.

Table 5: ANOVA for Response Surface Models for the nutritional content of dried tomato

Source	Df	Mean Square	Prob > F
	Quadratic model for % Protein Content		
Model	5	4.60	0.0026
T	1	9.45	0.0017
T	1	2.14	0.0506
T^2	1	2.98	0.0273
t^2	1	0.24	0.4592
Tt	1	7.37	0.0033
Residual	7	0.39	-
Lack of Fit	3	0.87	0.0016
Pure Error	4	0.020	-
Correlation Total	12	-	-
	Quadratic model for % Fat Content		
Model	5	8.53	0.0157
T	1	2.52	0.2140
T	1	2.52	0.2140
T^2	1	19.50	0.0067
t^2	1	2.03	0.2600
Tt	1	18.06	0.0081
Residual	7	1.35	-
Lack of Fit	3	3.05	0.0019
Pure Error	4	0.075	-
Correlation Total	12	-	-

Quadratic model for % Ash Content			
Model	5	12.00	0.0108
T	1	30.08	0.0037
T	1	4.08	0.1601
T^2	1	4.78	0.1328
t^2	1	20.98	0.0092
Tt	1	4.00	0.1638
Residual	7	1.65	-
Lack of Fit	3	3.19	0.0526
Pure Error	4	0.50	-
Correlation Total	12	-	-
Linear model for % Carbohydrate Content			
Model	2	52.74	0.0152
T	1	100.05	0.0055
T	1	5.43	0.4310
Residual	10	8.06	-
Lack of Fit	6	13.02	0.0054
Pure Error	4	0.61	-
Correlation Total	12	-	-
Quadratic model for % Fibre Content			
Model	5	0.51	0.0090
T	1	0.021	0.5909
T	1	0.19	0.1350
T^2	1	1.46	0.0022
t^2	1	1.46	0.0022
Tt	1	0.063	0.3618
Residual	7	0.066	-
Lack of Fit	3	0.15	-
Pure Error	4	0.000	-
Correlation Total	12	-	-
Quadratic model for % Caloric Value Content			
Model	5	628.00	0.0009
T	1	180.19	0.0631
T	1	530.40	0.0068
T^2	1	1277.90	0.0006
t^2	1	619.70	0.0046
Tt	1	915.06	0.0016
Residual	7	37.01	-
Lack of Fit	3	73.20	0.0413
Pure Error	4	9.88	-
Correlation Total	12	-	-

Values > *0.05* are not significant

T represents drying temperature

t represents drying time

3.9 Optimization of the Proximate Analyses and Model Validation

In the range of 50-70^{o}C for drying temperature and 16-20 hrs for drying time, where the goal for all the nutritional qualities was maximum, the predicted optimal values were 5.68% protein content, 7.62% fat content, 15.47% ash content, 72.61% carbohydrate content, 0.92% fibre content and 370.30 kCal calorific value at drying temperature of 55^{o}C and drying time of 17 hrs with a

desirability of 0.56. Under these optimal conditions, the experimental values were 5.36% protein content, 7.50% fat content, 15.00% ash content, 71.14% carbohydrate content, 1.00% fibre content and 333.5 kCal calorific value. The deviations between experimental and predicted values (0.39 - 37.01) were low and statistically insignificant which implies that the various models selected could actually predict the nutritional qualities of the dried tomatoes.

4. CONCLUSION

This study investigated the effect and optimization of drying parameters on the nutritional qualities of dried tomato. Models were developed and used to predict the quality of dried tomato. Protein content ranged from 0.70-6.48%, fat content ranged from 2.50-9.50, ash content ranged from 9-17%, carbohydrate content ranged from 68.12-81.22, fibre content ranged from 0.50-1.50 and the calorific value ranged from 348.50-397.00 kcal and fell within acceptable limits. The predicted optimal values were 5.68% protein content, 7.62% fat content, 15.47% ash content, 72.61% carbohydrate content, 0.92% fibre content and 370.30 kcal calorific value at drying temperature of 55^{o}C and drying time of 17 hrs with a desirability of 0.56. Under these optimal conditions, the experimental values were 5.36% protein content, 7.50% fat content, 15.00% ash content, 71.14% carbohydrate content, 1.00% fibre content and 333.50 kCal calorific value. The deviations between experimental and predicted values were low and statistically insignificant which implies that the various models selected could actually predict the nutritional qualities of the dried tomatoes. It was established that drying temperature and duration influenced the quality of dried tomato and optimum conditions are required for better nutritional quality retention. This will help to manage the issues of tomato post-harvest losses.

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