ISSN: 2449 – 0539
BAYERO JOURNAL OF ENGINEERING AND TECHNOLOGY (BJET) VOL.15 NO.1, JANUARY, 2020 pp57-68

Effect of Processing Parameters on Foam-mat Drying of Tomato (*Solanum lycopersicum)*

[1]Bosede Adelola Orhevba* and [2] Oladimeji Peter Alabi

[1,2]Department of Agricultural and Bioresources Engineering, Federal University of Technology, P.M.B 65, Minna, Niger State

Corresponding Author: [1]bosede.orhevba@futminna.edu.ng

Abstract:

Tomato is one of the most important fruit crops in the world; It is also very nutritious as it contains many essential nutrients. However, they are highly perishable and cannot be stored for very long in their raw form. In this study, tomato was dried using foam mat drying method with glycerol monostearate as foaming agent. The research was conducted using foaming agent ranging from 1- 3%, drying temperatures ranging from 65-75°C and whipping time of 3-7minutes. Design Expert Statistical Package was used to develop the experimental design. The proximate composition of the foam mat dried tomato was determined and its sensory evaluation was investigated. The results obtained ranged as follows: moisture content 19.84 - 16.94%, crude fibre 3.5-8.7%, crude protein 0.5-2.8%, fat content from 12.18 – 25.12%, ash content 10.01-20.5%, carbohydrate content 41.71 – 53.30%, vitamin content ranged from 2.65-4.99mg/100g. The result of the statistical analysis carried out indicated that the concentration of foaming agent had significant effect ($p < 0.05$) *on the odour and ash content of the tomato powder but did not have significant effect* ($p>0.05$) *on the other properties. The whipping time had no significant effect* ($p>0.05$) *on any of the properties of tomato powder. The drying temperature had significant effect* ($p < 0.05$) *on moisture content, crude fibre, fat, β-Carotene, odour and taste of the tomato powder. Thus, foam mat drying using glycerol monostearate is effective in retaining the nutritional and organoleptic qualities of tomato.*

Keywords: Tomato, foam mat drying, glycerol monostearate, nutritional properties.

Introduction

Tomato (Solanum *Lycopersicum)* belongs to the *Solanaceae* family. It is an herbaceous sprawling plant with weak and woody stem that grows as much as 1-3m in height. The flowers are yellowish in colour and the fruits of cultivated varieties may differ in size from cherry tomatoes of about 1–2 cm in size to beefsteak tomatoes, up to 10 cm or more in diameter. Most cultivars produce red fruits when they ripen (Satyanarayan and Ahmed, 1992). Tomato is one of the most important fruit crops in the world. It is ranked second in importance to potato in several countries (Parray *et al.,* 2007).

The *Solanaceae* family is made up of over 3000 species covering a very large diversity in terms of habit, habitat and morphology. Its species occur worldwide growing as large forest trees in wet rain forests to annual herbs in deserts (Knapp, 2002).

The world production of Tomato was around 105 million tonnes from the estimated 3.9 million hectares in 2001 (FAO, 2005). As it is a reasonably short time crop and gives high yield, it is economically attractive and is being increasingly cultivated (Naika, 2005). Nigeria ranks as the 16th largest tomato-producing nation in the world and has the comparative advantage and potential to lead the world in tomato production and exports. The production of tomatoes in Nigeria in 2010 was about 1.8 million metric tons; which accounts for about 68.4% of West Africa; 10.8% of Africa's total output and 1.28% of world output (FAO, 2010).

Tomato is used as condiments for stew, which is a regular feature of African meals making it an important ingredient in the confectionary industry. It is also an ingredient in many dishes and sauces and in drinks (Alam *et al.,* 2007). Today in Nigeria, it is very important in the diet of both rural and urban dwellers. According to Igene and Akinbolu (1994), tomato contains protein, edible oil, Vitamins A, B, C, and minerals (Igene and Akinbolu, 1994).

However, tomato fruits are highly perishable in nature and cannot be stored for very long in their raw form. Wastage predominantly occurs at the processing, packaging and distribution stages due to the poor processing technology, lack of good storage system and the transporting system used for the distribution of fresh tomatoes (Sangamithra *et al.,* 2015). These losses experienced by farmers discourage them from planting tomato to their full potential, which is an economic problem. Because of its high requirement, the country has to augment this need by importation of tomato. There is therefore the need for a cheap processing technique, which can store tomato for longer periods while retaining its nutritional and organoleptic properties. When this is achieved, it will reduce wastage, thereby encouraging the farmers to produce at a larger scale, which will improve Nigeria's economy and help the country reach its potential of leading the world in tomato production. Also, a reduction of post-harvest losses will increase food availability and impact the economic welfare of farmers (Sangamithra *et al.,* 2015).

There are several ways by which tomato fruits can be preserved and one of such considered in this study is foam-mat drying since it is a cheaper processing technique. Foam mat drying is a process in which liquid foods are whipped until they form stable foams and then air dried (Sankat and Castaigne, 2004). The process consists mainly of the formation of stable foam containing the product to be dried and the air-drying of the foam to form a thin porous sheet or mat. According to Sangamithra *et al.,* (2015), proteins, gums and various emulsifiers such as glycerol monostearate, propylene glycerol monostearate, carboxymethyl cellulose (CMC) and trichlorophosphate are used as foaming agents. The mixtures are whipped to form stable foams using blender or specially designed device. The foam is then spread as a thin sheet or mat and exposed to stream of hot air until it is dried to desired moisture content. Drying is carried out at relatively low temperatures to form a thin porous honeycomb sheet or mat, which is disintegrated to yield a free-flowing powder (Sangamithra *et al.,* 2015). The dried product obtained from foam mat drying is of better quality, porous and can be easily reconstituted. According to (Kudra and Ratti, 2006), the advantages of the foam mat drying process include suitability for all types of juices, rapid drying at lower temperature, retention of nutritional quality, easy reconstitution and cost-effective for producing easily reconstitutable juice powders. The foam mat drying process is described to be considerably cheaper than vacuum, freeze and spray drying methods (Kadam 2010a). They studied the quality of fresh and stored foam mat dried mandarin powder and reported desirable results in terms of the nutritional parameters and microbial quality of the foam-mat dried mandarin powder.

In this study, the aim is to adopt foam-mat drying technique for preserving and increasing the shelf life of tomato fruits and the effect of different processing parameters on the quality of products evaluated.

MATERIALS AND METHODS

Materials

Fresh tomatoes were obtained from a local farmer in Gidan Kwano village, Minna, Niger State. The experiment was carried out in the laboratories of the Department of Agricultural and Bio-Resources Engineering, School of Engineering and Engineering Technology, Federal University of Technology, Minna, Nigeria. Other materials used include oven, conical flask of various types, blender (Master chef MC-307B), digital weighing balance (AR3130), stainless steel tray and containers

Methods

The tomatoes were washed and good quality blemish-free ones were obtained after sorting. They were then blended into paste using a blender (Master chef MC-307B) (Plate 1).

ISSN: 2449 – 0539
BAYERO JOURNAL OF ENGINEERING AND TECHNOLOGY (BJET) VOL.15 NO.1, JANUARY, 2020 pp57-68

Plate 1: Tomato Paste

Preparation of Tomato Foam

The levels of various input variables selected were as follows: concentration of GMS: 1, 2 and 3%, Whipping Time: 3, 5 and 7 mins, and drying temperature 65, 70 and 75°C. These values were arrived at after extensive literature review and preliminary tests had been carried out. The required quantity of glycerol mono-stearate was added to 220g of tomato paste and whipped at high speed with the blender (500W, 18,000 rpm) for a time as defined by Table 1 (Experimental design). The Box Bhenken experimental design was done using Design Expert Version 7.

Table 1: Experimental Design of the study

Run	Foaming agent (%)	Whipping time (min)	Temperature (°C)
1	1	5	65
2	3	5	65
3	2	3	65
4	2	7	65
5	1	3	70
6	1	7	70
7	3	3	70
8	3	7	70
9	2	5	70
10	1	5	75
11	3	5	75
12	2	3	75
13	2	7	75
14	2	5	70
15	2	5	70
16	2	5	70
17	2	5	70

Preparation of Tomato powder

The resulting foams formed were then spread on trays and dried using the hot air oven at temperature ranging from (65-75°C) for 5.5 hours (Plate 2).

Preparation of foaming agent

To obtain 20% GMS, 20g of glycerol monostearate was measured and dissolved in 80ml of water at 100°C and then transferred to a blender where it was whipped till a clear uniform solution was achieved. It was then allowed to cool before use.

Plate 2: Blended and whipped samples in the oven for drying

After drying, the tomato flakes were scraped from the trays and blended into powder. The powder was then stored in an airtight container at room temperature until analysis was carried out (Plate 3).

Plate 3: Samples of dried tomato powder

Analysis

The properties determined include nutritional and organoleptic properties.

Nutritional Analysis

The nutritional properties determined were moisture content, crude fibre, crude protein, fat content, ash, carbohydrate and β-carotene. These were determined using the methods described by the Association of Official Analytical Chemists (AOAC, 2005).

Determination of Moisture content

Moisture cans were washed; oven dried and weighed using analytical weighing balance as W_1.

Two (2g) grams of the sample was put into previously weighed moisture can, it was then weighed and recorded as W_2. The sample in the moisture can was put into the oven at 105°C for 3 hours. The sample was removed and placed in the desiccator to cool and weighing was carried out afterwards. The sample was reheated and cooled intermittently until constant mass was obtained as W_3. The difference in mass as percent moisture was calculated as the percentage moisture content.

$$\%\ Moisture\ content = \frac{W_2 - W_1}{W_3 - W_2} \times 100 \quad (1)$$

W_1 = weight of moisture dish
W_2 = weight of moisture dish and sample (wet)
W_3 = weight of moisture dish and sample (dry)

Determination of Crude Fibre

About 2g of each sample was weighed (and recorded as W_0) into a 500 ml conical flask and 100 ml of digestion reagent was added. It was then brought to boiling and refluxed for 40 minutes exactly counting from the start of boiling. The flask was removed from the heater, cooled a little then filtered through a filter paper. The residue was washed with hot water, stirred once with a spatula and transferred to a porcelain dish. The sample was dried overnight at 105°C. After drying, it was transferred to a desiccator and weighed as W_1. It was then burnt in a muffle furnace at 500°C for 6 hours, allowed to cool, and reweighed as W_2.

$$Percentage\ crude\ fibre = \frac{W_1 - W_2}{W_0} \times 100 \quad (2)$$

Where:
W_1= Weight of crucible + fibre + ash
W_2= Weight of crucible + ash
W_0= Dry weight of sample

Determination of Crude Protein

The Kjeldahl apparatus was used for the determination of crude protein. About 0.5g of the sample was weighed and put into a Kjeldahl digestion flask. A pinch of mixed catalyst was added into each of the flask moistened with distilled water and mixed with 12 ml of concentrated H_2SO_4. The mixture was heated to red-hot temperature under a fume cupboard for 2 hours to obtain a clear solution. The digest was transferred quantitatively to 100 ml volume flask and diluted to mark with distilled water. A portion of the digest (10 ml) was mixed with equal volume of 40% NaOH solution in a semi-micro Kjeldahl distillation apparatus. The mixture was distilled and the distillate collected into 10 ml of 2% boric solution containing 3 drops of mixed indicator (methyl-orange). The distillate was collected and titrated against 0.1M of H_2SO_4 solution. A blank experiment was also set involving digestion of all the materials except the sample. The distillation was also carried out on the blank. The titre value of the blank was subtracted from that of the sample and the difference obtained was used to calculate the crude protein. The total nitrogen content of the sample was calculated using equation 3.

$$\%\ Protein = \frac{(A-B) \times Molarity\ of\ H2SO4\ \times 1.4007 \times 6.25}{W} \times 100 \quad (3)$$

Where A = titre value
B = blank titre value
W = weight of sample

Determination of Fat Content

2g of sample wrapped in a filter paper was weighed using a chemical balance. It was then placed in an extraction thimble that was previously cleaned, dried in an oven, and cooled in the desiccator before weighing. Thereafter, about 25 ml of solvent was measured into the flask and the fat content was extracted. After extraction, the solvent was evaporated by drying in the oven. The flask and its contents were cooled in a desiccator and weighed. The percentage fat content was calculated using equation 4.

$$\%\ of\ fat\ content = \frac{weight\ of\ extracted}{weight\ of\ sample} \times 100 \quad (4)$$

Determination of Ash

About 5g of finely ground sample was weighed into clean, dried previously weighed crucible with lid (W_1). The sample was ignited over a low flame to char the organic matter with lid removed. The crucible was placed in muffle furnace at 600^0C for 6hours until it ashed completely. It was then transferred directly to desiccators, cooled and weighed immediately (W_2).

$$\% \, Ash = \frac{W1 - W2}{weight \; of \; sample} \times 100 \qquad (5)$$

Determination of Carbohydrate

The carbohydrate was determined by the method of difference where the mean values of other parameters were determined from one hundred (100).

$$\% \, Carbohydrate = 100\% - (\%M.C + \%C.P + C.F + \%Fat + \% \, Ash) \qquad (6)$$

Where;
M.C = Moisture Content
C.P = Crude Protein
C.F = Crude fibre.

Determination of β-Carotene

1g of Tomato powder was placed into a conical flask containing 30ml of 85% of acetone. The funnel was swirled gently to obtain a homogenous mixture. The spectrophotometer was set up to a wavelength of 644nm and cuvette-containing acetone (blank) was used to calibrate to zero point. Sample of each extract was placed in a cuvette and readings were taken when the figure became steady. This procedure was repeated for wavelength 633 and 425.5 and the absorbance readings were used to calculate the β -Carotene Content.

$$C_{a+b} = 6.4Q_{633} + 18.8D_{644} \qquad (7)$$

$$\text{B-Carotene} = 4.75D_{425.5} - 0.226C_{a+b} \qquad (8)$$

Where D and Q are absorbance readings.

Organoleptic Analysis

Organoleptic evaluation of the reconstituted tomato was done by a 10-man panel. This was done based on the method described by (Onwuka, 2005). The panellists were asked to rate the samples for taste, odour and colour on a 9-point hedonic scale as follows:
Taste: 9 indicating “extremely appealing” and 1 “extremely unappealing”
Odour: 9 indicating “extremely pleasant” and 1 “extremely unpleasant”
Colour: 9 indicating “extremely bright red” and 1 “extremely dull red”

Statistical Analysis

The data obtained from the study was analysed using analysis of variance (ANOVA) which was carried out using Design Expert 7 for windows. The ANOVA was used to determine the statistical significance of the processing parameters (forming agent, whipping time and drying temperature) on the output characteristics (Nutritional and organoleptic properties) of the foam mat dried tomato powder.

RESULTS AND DISCUSSION

Results

The results of the nutritional and organoleptic composition of foam mat dried tomato using glycerol mono-stearate are presented in Tables 2 – 5.

Table 2: Proximate composition of foam mat dried tomato samples.

Run	FA (%)	WT (min)	DT (°C)	MC (%)	CF (%)	Protein (%)	Fat (%)	Ash (%)	CHO (%)	B-Carotene (mg/100g)
$T_{1,5,65}$	1	5	65	19.84±1.21	8.71±0.21	2.83±0.28	16.75±1.18	11.32±1.03	40.59±0.78	3.55±0.12
$T_{3,5,65}$	3	5	65	19.16±0.84	7.2±1.01	1.75±0.11	20.62±1.31	10.13±0.81	41.17±1.04	3.18±0.08
$T_{2,3,65}$	2	3	65	19.79±0.55	6.43±0.63	0.35±0.03	17.63±0.98	11.22±1.11	44.63±1.11	2.65±0.17
$T_{2,7,65}$	2	7	65	18.85±0.62	6.41±0.82	1.05±0.06	16.61±1.07	13.92±0.86	43.19±0.84	3.90±0.16
$T_{1,3,70}$	1	3	70	18.44±0.21	6.63±0.66	2.45±0.71	18.19±0.67	11.23±0.72	43.32±0.92	3.70±0.06
$T_{1,7,70}$	1	7	70	18.31±1.11	5.33±1.10	1.75±0.21	16.02±0.82	20.53±1.04	38.12±0.77	3.70±0.13
$T_{3,3,70}$	3	3	70	19.02±0.23	4.62±0.29	2.11±0.07	12.18±0.58	13.41±0.56	48.47±1.13	3.52±0.34
$T_{3,7,70}$	3	7	70	17.32±0.72	4.41±0.71	1.42±0.09	22.07±1.11	12.33±0.62	42.51±0.74	3.39±0.07
$T_{2,5,70}$	2	5	70	18.75±0.67	5.22±1.31	1.05±0.23	20.04±0.95	12.51±0.81	42.56±0.86	4.51±0.81
$T_{1,5,75}$	1	5	75	18.72±0.25	3.52±0.18	1.05±0.07	20.13±1.02	18.43±1.01	38.22±1.02	4.12±0.16
$T_{3,5,75}$	3	3	75	16.94±1.12	4.34±1.10	1.05±0.01	22.45±0.83	12.52±0.78	42.66±1.13	4.75±0.48
$T_{2,3,75}$	2	3	75	18.45±0.97	5.33±0.91	1.75±0.22	23.58±1.22	20.41±0.99	30.52±0.54	3.65±0.04
$T_{2,7,75}$	2	7	75	18.71±1.03	5.21±0.83	1.75±0.27	25.12±0.68	11.32±0.72	37.93±0.11	3.68±0.18
$T_{1,5,65}$	2	5	70	18.75±0.82	5.23±0.67	1.05±0.04	20.16±0.86	12.53±0.08	42.51±1.16	4.99±0.46
$T_{3,5,65}$	2	5	70	18.75±1.12	5.02±1.21	1.05±0.20	20.37±1.02	12.56±1.01	42.51±0.81	4.99±0.61
$T_{2,3,65}$	2	5	70	18.75±1.22	5.22±0.26	1.05±0.06	20.41±0.86	12.52±0.28	42.51±1.26	4.99±0.71
$T_{2,7,65}$	2	5	70	18.75±0.81	5.24±0.12	1.05±0.01	20.33±1.18	12.53±0.46	42.51±0.91	4.99±0.26
	Control			92.3±2.07	1.16±0.04	0.91±0.02	0.65±0.16	2.71±0.02	2.29±0.06	3.64±0.04

Table 3: Scores obtained for colour

Sample	1	2	3	4	5	6	7	8	9	**Mean**
$T_{1,5,65}$	6	2	5	6	5	4	3	5	6	4.7
$T_{3,5,65}$	4	5	6	7	4	9	2	6	6	5.4
$T_{2,3,65}$	5	4	8	6	4	8	5	5	7	5.8
$T_{2,7,65}$	5	4	6	8	5	2	2	5	8	5.1
$T_{1,3,70}$	6	5	7	6	5	3	5	5	7	5.6
$T_{1,7,70}$	7	6	8	7	6	7	4	6	7	6.4
$T_{3,3,70}$	7	6	6	6	7	2	1	6	6	5.2
$T_{3,7,70}$	7	5	6	6	6	7	2	7	7	5.9
$T_{2,5,70}$	7	6	4	4	8	3	3	6	5	4.8
$T_{1,5,75}$	4	5	3	5	8	5	6	5	5	5
$T_{3,5,75}$	3	6	6	5	4	6	4	7	6	5.4
$T_{2,3,75}$	5	6	4	4	5	6	3	6	4	4.8
$T_{2,7,75}$	5	6	8	6	6	1	3	6	8	4.9

Table 4: Scores obtained for Odour

Sample	1	2	3	4	5	6	7	8	9	**Mean**
$T_{1,5,65}$	6	7	7	6	6	6	6	7	7	6.4
$T_{3,5,65}$	4	7	6	6	6	4	5	7	6	5.7
$T_{2,3,65}$	5	6	7	7	5	5	5	6	6	5.8
$T_{2,7,65}$	5	8	6	7	5	8	5	7	7	6.4
$T_{1,3,70}$	5	8	6	6	6	9	4	8	6	6.4
$T_{1,7,70}$	6	6	7	7	5	4	4	6	7	5.8
$T_{3,3,70}$	5	7	7	7	5	4	4	7	7	5.9
$T_{3,7,70}$	5	8	7	6	6	5	3	7	8	6.1
$T_{2,5,70}$	4	6	6	6	8	2	3	5	6	5.1
$T_{1,5,75}$	7	6	5	5	7	8	6	7	6	6.3
$T_{3,5,75}$	5	8	6	4	6	3	6	8	4	5.6
$T_{2,3,75}$	5	7	6	5	7	7	5	7	7	6.2
$T_{2,7,75}$	6	5	3	4	6	8	4	6	4	5.1

Table 5: Scores obtained for Taste

Run	1	2	3	4	5	6	7	8	9	**Mean**
$T_{1,5,65}$	5	5	8	6	6	6	6	5	7	6
$T_{3,5,65}$	5	6	6	6	5	5	6	6	6	5.7
$T_{2,3,65}$	6	5	8	7	7	7	6	6	7	6.6
$T_{2,7,65}$	6	6	7	8	6	5	5	6	8	6.3
$T_{1,3,70}$	6	5	8	8	6	6	4	5	7	6.1
$T_{1,7,70}$	7	6	8	8	5	6	4	6	8	6.4
$T_{3,3,70}$	5	5	8	6	6	7	3	5	8	5.9
$T_{3,7,70}$	6	6	8	7	7	6	3	7	8	6.4
$T_{2,5,70}$	6	6	6	4	5	7	3	6	5	5.3
$T_{1,5,75}$	6	5	5	7	6	5	3	7	8	5.8
$T_{3,5,75}$	4	7	7	8	5	7	2	8	6	6
$T_{2,3,75}$	5	7	7	6	5	7	2	6	8	5.9
$T_{2,7,75}$	5	8	6	6	6	6	2	6	7	5.8

Discussion

Proximate composition

Moisture Content

From Table 2, it can be seen that sample $T_{3,\ 5,\ 75}$ (with foaming agent at 3%, whipped for 5 minutes and dried at 75^0C) had the lowest moisture content of 16.94%. The moisture content values are higher than the value of 8.05% reported by Adejumo (2012) for oven- dried tomato powder which was dried at 60^0C, they also reported that the drying method and pretreatments used had significant effects ($p < 0.05$) on the moisture content of tomato powder.

Table 6 shows that percentage foaming agent and whipping time have no significant effect ($p>0.05$) on moisture content; the interaction between the processing factors also didn't have significant effect on the moisture content. However, temperature has significant effect ($p<0.05$) on the moisture content, the higher the temperature, the lower the moisture content.

Table 6: ANOVA for Moisture content

Source	Sum of Squares	Df	Mean Square	F Value	p-value Prob > F	
Model	6.87912	9	0.76435	4.41423	0.0315	Significant
A-Foaming agent (%)	0.82521	1	0.82521	4.76573	0.0653	
B-Whipping time (min)	0.51839	1	0.51839	2.99379	0.1272	
C-Temp °C	2.49515	1	2.49515	14.4099	0.0067	
AB	0.29649	1	0.29649	1.71226	0.232	
AC	0.17989	1	0.17989	1.0389	0.342	
BC	0.77733	1	0.77733	4.48919	0.0719	
A^2	0.49105	1	0.49105	2.83589	0.1361	
B^2	0.18333	1	0.18333	1.05877	0.3377	
C^2	0.40785	1	0.40785	2.35539	0.1687	
Residual	1.21209	7	0.17316			
Lack of Fit	1.21009	3	0.40336	806.724	< 0.0001	Significant
Pure Error	0.002	4	0.0005			
Cor Total	8.0912	16				

Crude Fibre

From Table 2, it can be seen that crude fibre of the samples increased from 1.16% (control) to the highest value (8.7%) for sample $T_{1,\ 5,\ 65}$ (with foaming agent at 1%, whipped for 5 minutes and dried at 65^0C) and lowest value (3.5%) for sample $T_{1,\ 5,\ 75}$ (with foaming agent at 1%, whipped for 5 minutes and dried at 75^0C). Famurewa and Raji (2011) also reported an increase in the crude fibre value after drying of tomato (from 0.16% for the control to 0.28% after oven drying). They reported that the difference in fibre content of the control and dried tomatoes indicate availability of more crude fibre in the dried ones; it therefore implies that there are more indigestible materials in the dried tomato. Table 7 shows that the amount of foaming agent and whipping ($p>0.05$) time have no significant effect on the crude fibre but temperature ($p<0.05$) has significant effect on crude fibre.

Table 7: ANOVA for Crude Fibre.

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Model	16.857	6	2.8095	4.04926	0.0254	significant
A-Foaming agent (%)	1.40899	1	1.40899	2.03075	0.1846	
B-Whipping time (min)	0.34027	1	0.34027	0.49042	0.4997	
C-Temp °C	12.3959	1	12.3959	17.8658	0.0018	
AB	0.32285	1	0.32285	0.46532	0.5106	
AC	1.32747	1	1.32747	1.91324	0.1967	
BC	0.00355	1	0.00355	0.00511	0.9444	
Residual	6.9383	10	0.69383			
Lack of Fit	6.9383	6	1.15638			
Pure Error	0	4	0			
Cor Total	23.7953	16				

Crude Protein

Table 2 shows that crude protein majorly increased after foam mat drying. Sample $T_{1,5,65}$ (with foaming agent at 1%, whipped for 5 minutes and dried at 65^0C) has the highest protein content (2.8%), while sample $T_{2,3,65}$ (with foaming agent at 2%, whipped for 3 minutes and dried at 65^0C) has the lowest protein content (0.35%). The result was compared to that reported by (Famurewa and Raji, (2011) and Opadotun *et al.*, 2016), who reported that crude protein values for oven-dried tomato (dried at $40^{0/}$C until constant weight was achieved; dried at 65^0C for 72 hours) reduced from 28.95% and 28.97% for the control to 13.22% and 13.25% after oven drying. Table 8, shows that neither the amount of foaming agent nor whipping time nor temperature ($p>0.05$) had significant effect on the protein content.

Table 8: ANOVA for Protein

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Model	0.74766	6	0.12461	0.23298	0.9559	not significant
A-Foaming agent (%)	0.36657	1	0.36657	0.68536	0.4271	
B-Whipping time (min)	0.01196	1	0.01196	0.02237	0.8841	
C-Temp °C	0.01562	1	0.01562	0.0292	0.8677	
AB	0.04322	1	0.04322	0.08081	0.782	
AC	0.23899	1	0.23899	0.44683	0.519	
BC	0.02506	1	0.02506	0.04685	0.833	
Residual	5.34852	10	0.53485			
Lack of Fit	5.34852	6	0.89142			
Pure Error	0	4	0			
Cor Total	6.09618	16				

Fat Content

As seen in Table 2, the fat content generally increased. The sample $T_{2,7,75}$ (with foaming agent at 2%, whipped for 7 minutes and dried at 75^0C) has the highest fat content (25.12%) while sample $T_{3,3,70}$ (with foaming agent at 3%, whipped for 3 minutes and dried at 70^0C) has the lowest fat content (12.18%).

The result obtained was compared to that reported by Opadotun *et al.*, (2016); who reported a decrease; the fat content for tomato reduced from 1.77% for the control to 1.19% after oven drying (dried at 65^0C for 72 hours). Table 9 shows that the amount of foaming agent and whipping time ($p>0.05$) are not significant in affecting the fat content while temperature ($p<0.05$) has significant effect on the fat content. The higher the temperature the higher the fat content.

Table 9: ANOVA for Fat

Source	Sum of Squares	Df	Mean Square	F Value	p-value Prob > F	
Model	126.99	9	14.11	3.76723	0.0471	significant
A-Foaming agent (%)	15.4091	1	15.4091	4.11408	0.0821	
B-Whipping time (min)	6.54689	1	6.54689	1.74796	0.2277	
C-Temp °C	71.1639	1	71.1639	19.0001	0.0033	
AB	31.9616	1	31.9616	8.53342	0.0223	
AC	3.1445	1	3.1445	0.83955	0.39	
BC	0.55435	1	0.55435	0.14801	0.7119	
A^2	5.1338	1	5.1338	1.37068	0.28	
B^2	7.57159	1	7.57159	2.02154	0.1981	
C^2	24.1793	1	24.1793	6.45564	0.0386	
Residual	26.2182	7	3.74546			
Lack of Fit	26.2182	3	8.73939			
Pure Error	0	4	0			
Cor Total	153.208	16				

Ash content

Table 2 shows that the ash content of tomato generally increased in the samples. The sample with the highest ash content (20.5%) is sample $T_{1,7,70}$ (with foaming agent at 1%, whipped for 7 minutes and dried at 70^0C) while sample $T_{1,3,70}$ (with foaming agent at 1%, whipped for 3 minutes and dried at 70^0C) has the lowest ash content (11.0%). Adejumo (2012) also reported an increase in ash content of dried tomato powder; they reported that the ash content of oven-dried tomato samples (dried at 60^0C until constant weight was achieved) increased from 1.03% (control) to 2.50% after oven drying. From Table 10, it can be seen that only the amount of foaming agent ($p<0.05$) had significant effect on the ash content of foam mat dried tomato.

Table 10: ANOVA for Ash

Source	Sum of Squares	Df	Mean Square	F Value	p-value Prob > F	
Model	110.629	6	18.4382	3.66811	0.0343	significant
A-Foaming agent (%)	34.1327	1	34.1327	6.79039	0.0262	
B-Whipping time (min)	2.0853	1	2.0853	0.41485	0.534	
C-Temp°C	16.8963	1	16.8963	3.36136	0.0966	
AB	20.2626	1	20.2626	4.03107	0.0724	
AC	17.1811	1	17.1811	3.41802	0.0942	
BC	26.3082	1	26.3082	5.23378	0.0452	
Residual	50.2662	10	5.02662			
Lack of Fit	50.2662	6	8.37769			
Pure Error	0	4	0			
Cor Total	160.895	16				

Carbohydrate Content

From Table 2, the carbohydrate content of the samples increased after subjecting them to foam mat drying from a value of 2.29% (control). Sample $T_{3,\,3,\,70}$ (with foaming agent at 3%, whipped for 3 minutes and dried at 70^0C) has the highest carbohydrate content of 53.30% while sample $T_{1,\,5,\,75}$ (with foaming agent at 1%, whipped for 5 minutes and dried at 75^0C) has the lowest value of 41.71%. Opadotun *et al.*, (2016) also reported an increase in carbohydrate content of dried tomato powder compared with the fresh sample; they reported that the carbohydrate content increased from 8.75% (control) to 27.27% for the oven dried sample (dried at 65^0C for 72 hours). Famurewa and Raji (2011) however reported a decrease in the carbohydrate value for oven-dried tomato (dried at 40^0C until constant weight was achieved) compared with the fresh sample. They also reported a reduction from 41.15% (control) to 36.03% for the oven dried sample. Table 11 shows that neither the percentage foaming agent nor whipping time nor drying temperature ($p>0.05$) have significant effect on the carbohydrate content of the tomato powder.

Table 11: ANOVA for Carbohydrate

Source	Sum of Squares	Df	Mean Square	F Value	p-value Prob > F	
Model	103.768	6	17.2947	1.35192	0.3206	not significant
A-Foaming agent (%)	27.6835	1	27.6835	2.16401	0.172	
B-Whipping time (min)	5.71668	1	5.71668	0.44687	0.519	
C-Temp °C	45.755	1	45.755	3.57666	0.0879	
AB	1.30636	1	1.30636	0.10212	0.7559	
AC	4.31327	1	4.31327	0.33717	0.5743	
BC	16.0367	1	16.0367	1.25359	0.289	
Residual	127.927	10	12.7927			
Lack of Fit	127.925	6	21.3208	42641.6	0.0001	Significant
Pure Error	0.002	4	0.0005			
Cor Total	231.695	16				

β-Carotene

From Table 2, the β-Carotene content of foam mat dried tomato was highest (4.49mg/100g) in sample $T_{2,\,5,\,70}$ (with foaming agent at 2%, whipped for 5 minutes and dried at 70^0C) and least (2.65mg/100g) in sample $T_{2,\,3,\,65}$ (with foaming agent at 2%, whipped for 3 minutes and dried at 65^0C) The result was compared with that reported by Hussein *et al.*, (2016) for the sun drying of tomato slices in which the value of β-Carotene increased from 4.15% (control) to 4.94% after sun drying. Table 12 shows that only the temperature ($p<0.05$) has significant effect on the vitamin content.

Table12: ANOVA for β-Carotene

Source	Sum of Squares	Df	Mean Square	F Value	p-value Prob > F	
Model	7.3759	9	0.81954	5.18212	0.0206	significant
A-Foaming agent (%)	0.00432	1	0.00432	0.02733	0.8734	
B-Whipping time (min)	0.07492	1	0.07492	0.47372	0.5134	
C-Temp°C	1.17858	1	1.17858	7.45238	0.0293	
AB	0.07144	1	0.07144	0.45172	0.5231	
AC	0.42495	1	0.42495	2.68703	0.1452	
BC	0.7079	1	0.7079	4.47615	0.0722	
A^2	0.66559	1	0.66559	4.20863	0.0794	
B^2	2.30921	1	2.30921	14.6015	0.0065	
C^2	1.03983	1	1.03983	6.57501	0.0373	
Residual	1.10704	7	0.15815			
Lack of Fit	0.91417	3	0.30473	6.31996	0.0535	not significant
Pure Error	0.19287	4	0.04822			
Cor Total	8.48294	16				

Colour

From Table 3 it can be seen that sample $T_{1, 7, 70}$ (with foaming agent at 1%, whipped for 7 minutes and dried at 70^0C) has the best colour acceptability of 6.4. The samples dried at 65°C generally have greater colour acceptability. Table 13 shows that none of the parameters significantly affect colour.

Table 13: ANOVA for Colour

Source	Sum of Squares	Df	Mean Square	F Value	p-value Prob > F	
Model	3.04408	9	0.33823	2.24797	0.1491	not significant
A-Foaming agent (%)	0.00884	1	0.00884	0.05872	0.8155	
B-Whipping time (min)	0.05479	1	0.05479	0.36417	0.5652	
C-Temp°C	0.25419	1	0.25419	1.68938	0.2348	
AB	0.08699	1	0.08699	0.57813	0.4719	
AC	0.18371	1	0.18371	1.22099	0.3057	
BC	0.04919	1	0.04919	0.32695	0.5853	
A^2	0.69113	1	0.69113	4.59339	0.0693	
B^2	1.50058	1	1.50058	9.97326	0.016	
C^2	0.19043	1	0.19043	1.26566	0.2977	
Residual	1.05322	7	0.15046			
Lack of Fit	1.05322	3	0.35108			
Pure Error	0	4	0			
Cor Total	4.09731	16				

Odour

Table 4 shows that $T_{1, 5, 65}$ (with foaming agent at 1%, whipped for 5 minutes and dried at 65^0C), $T_{2, 7, 65}$ (with foaming agent at 2%, whipped for 7 minutes and dried at 65^0C) and $T_{1, 3, 70}$ (with foaming agent at 1%, whipped for 3 minutes and dried at 70^0C) have greater odour acceptability of 6.4. Table 14 shows that the amount of foaming agent and temperature significantly ($p<0.05$) affected the odour. The whipping time alone did not significantly affect odour but when in combination with amount of foaming agent or temperature ($P<0.05$) the effect becomes significant.

Table 14: ANOVA for Odour

Source	Sum of Squares	Df	Mean Square	F Value	p-value Prob > F	
Model	4.11844	9	0.4576	6.08457	0.0132	significant
A-Foaming agent (%)	0.63438	1	0.63438	8.43508	0.0228	
B-Whipping time (min)	0.05019	1	0.05019	0.66738	0.4409	
C-Temp °C	0.32804	1	0.32804	4.36182	0.0751	
AB	0.35575	1	0.35575	4.73027	0.0661	
AC	0.07269	1	0.07269	0.96658	0.3583	
BC	0.61073	1	0.61073	8.12058	0.0247	
A^2	0.82105	1	0.82105	10.9172	0.013	
B^2	0.63232	1	0.63232	8.40768	0.023	
C^2	0.3311	1	0.3311	4.40244	0.0741	
Residual	0.52645	7	0.07521			
Lack of Fit	0.52645	3	0.17548			
Pure Error	0	4	0			
Cor Total	4.64489	16				

Taste

Table 5 shows that the sample with the best taste acceptability (6.6) is $T_{2, 3, 65}$ (with foaming agent at 2%, whipped for 3 minutes and dried at 65^0C). Table 15 shows that Temperature ($p<0.05$) has a significant effect on the taste of tomato powder produced.

Table 15: ANOVA for Taste

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Model	2.64205	9	0.29356	7.07558	0.0086	Significant
A-Foaming agent (%)	0.08642	1	0.08642	2.08297	0.1922	
B-Whipping time (min)	0.03283	1	0.03283	0.79125	0.4033	
C-Temp °C	0.30802	1	0.30802	7.42405	0.0296	
AB	0.0078	1	0.0078	0.18799	0.6776	
AC	3.42E-05	1	3.42E-05	0.00082	0.9779	
BC	0.00096	1	0.00096	0.02302	0.8837	
A^2	0.22131	1	0.22131	5.33423	0.0542	
B^2	1.51836	1	1.51836	36.5964	0.0005	
C^2	0.09308	1	0.09308	2.24339	0.1779	
Residual	0.29043	7	0.04149			
Lack of Fit	0.29043	3	0.09681			
Pure Error	0	4	0			
Cor Total	2.93248	16				

CONCLUSIONS

Foam mat drying using glycerol monostearate is effective in retaining the nutritional qualities of tomato. The concentration of foaming agent has significant effect on the odour and ash content of tomato powder produced but does not have significant effect on the other properties. The whipping time has no significant effect on any of the properties of tomato powder produced. The drying temperature has significant effect on Moisture, Crude fibre, fat, β-Carotene, odour and taste of the tomato powder produced. Sample $T_{2, 5, 70}$ has the highest β-Carotene content. It can therefore be concluded that foam mat drying is effective in retaining the colour, odour and taste of tomato.

REFERENCES

Adejumo, B.A. (2012). Effects of Drying Methods and Pretreatment on some Physiochemical Quality Attributes of tomato Powder. *International Journal of Innovative Research and Development.* 1(11): 50 -58.

Alam, T., Tanweer, G., and Goyal, G.K. (2007). Packaging and storage of Tomato Puree and Paste. *Stewart Postharvest Review*, 3, (5):1-8.

AOAC. (2005). *Official Methods of Analysis of the Association of Analytical Chemists International*, 18th ed. Gathersburg, MD U.S.A. Official methods.

Famurewa J. A and Raji A. O (2011). Physicochemical Characteristics of Osmotically Dehydrated Tomato (*Lycopersicon esculentum*) under different Common Drying Methods. *International Journal of Biological and Chemical Sciences*. 5(3):1304-1309.

FAO. (2005). The State of Food and Agriculture. Food and Agriculture Organization of the United Nations, Rome, FAO Agriculture series.

FAO. (2010). Food and Agricultural Organization of the United Nations. FAOSTAT, 2010. Available: http://faostat.fao.org/Accessed on 28th June 2017

Hussein, J.B., Sanusi, M.S., and Filli, K. B (2016). Evaluation of Drying Methods on the Content of some Bio-actives (lycopene, β-carotene and ascorbic acid) of Tomato Slices. *African Journal of Food Science.* 10(12):359-367.

Igene, J.O., Akinbolu, A.M (1994). Post-Harvest Preservation Technologies for Fadama Products; In Kolawole, A; I. Scones, M. 0. Awogbade, J.P. (eds) *Strategies for the Sustainable use in Fadama lands in Northern Nigeria, Zaria,* Pp 97.

Kadam, D.M., Patil, R.T. and Kaushik, P (2010). Foam mat Drying of Fruit and Vegetable Products; In *Drying of foods, Vegetables and Fruits – Volume 1* (S.V. Jangam, C.L. Law and A.S. Mujumdar, eds) pp. 113–124, ISBN: 978-981-08-6759-1.

Knapp, S. (2002). Tobacco to Tomatoes: A Phylogenetic Perspective on Fruit Diversity in the Solanaceae". *Journal of Experimental Botany*, 53:2001-2022.

Kudra, T., and Ratti, C (2006). Foam-mat drying: Energy and Cost Analyses. *Can. Biosyst. Eng*. 48:3.27–3.32.

Naika S**.,** Juede J., Goffau M., Hilmi M., Dam V (2005). Cultivation of Tomato. *Production, Processing and Marketing, Agromisa/ CTA Revised edition,* Agrodok – series No 17.

Onwuka, G.I. (2005). Food Analysis and Instrumentation: Theory and Practice. Naphthali Prints, Surulere, Lagos, Nigeria.

Opadotun, O.O., Adekeye, S.A., Ojukwu, E.O., and Adewumi, A.A., (2016). Comparative Analysis of Nutritional Values of Tomatoes Subjected to Different Drying Conditions. *International Journal of Basic and Applied Sciences.* 1(5):6-9.

Parray, B.A. Ganai, A.M. and Fazli, K.M (2007). Physicochemical Parameters and Growth Yield of Tomato: Role of Farmyard Manure and Neemcake. *American-Euroasian Journal of Agriculture and Environmental Science*, 1(2):302 – 307.

Sangamithra A., Sivakumar V., Sawmy G. J., and Kannan K (2015). Foam mat Drying of Food materials: A Review. *Journal of Food Processing and Preservation,* 39:3165–3174.

Sankat, C.K. and Castaigne, F (2004). Foaming and Drying Behaviour of Ripe Bananas". *LWT – Food Science and Technology.* 37:517–525.

Satyanarayan, S. and Ahmed, M.S (1992). Production and Marketing of Tomatoes in Tribal Area of District Sidhi (M.P.) *Indian journal of Agricultural Marketing,* 61(1):50-59.