Process conditions governing the drying rate and quality of tomato powder obtained from foam-mat dried tomato paste

Adesoji Matthew Olaniyan[1], Musliu Olushola Sunmonu[2], Michael Mayokun Odewole[2], Olusanjo Oluwaseun Ige[2]

1 – Department of Agricultural and Bioresources Engineering, Faculty of Engineering, Federal University, Oye-Ekiti, PMB 373, Ekiti State, Nigeria.
2 - Department of Food and Bioprocess Engineering, Faculty of Engineering and Technology, University of Ilorin, PMB 1515, Ilorin, Kwara State, Nigeria.

Keywords:

Foam-mat
Drying rate
Tomato
Paste
Powder.

Article history:

Received 18.07.2015
Received in revised form 01.09.2015
Accepted 24.09.2015

Corresponding author:

Michael Mayokun Odewole
E-mail:
odewole2005@yahoo.com

Abstract

Introduction. One of the most effective ways of reducing postharvest losses in food materials is drying. However, prolonged time of drying has the tendency of reducing the quality characteristics of highly perishable produce like tomato.

Materials and methods. Fresh tomato ("dan UTC" variety), foaming agent (egg white), foam stabilizer (Carboxyl Methyl Cellulose), digital scale (OHAUS 3001), laboratory air-oven (model MINO50–10G039), blender (400 W, model number FPO12A). Vitamin C and protein content were determined using AOAC (2002) standard.

Results and discussion. Increase in the quantity of foaming agent (from 5 – 10 %) caused a decrease in drying rate from 20.63 g/h to 18.57 g/h, however, a further increase in foaming agent (10-15 %) caused the drying rate to increase from 18.57g/h to 20.63g/h. Increase in the percentage of foaming agent (5 % to 15 %) led to a slight increase in the values of protein content (from 24.65% to 24.7889 %).Increase in the quantity of foaming agent did not cause the vitamin C content of the dried tomato powder to fall below 1.3 %, however, as the foaming agent increased, the vitamin C content showed a reduction in its values. Increase in the percentage of foam stabilizer (0.15 – 0.75 %) caused an increase in drying rate from 19.33 g/h to 20.62 g/h. The trend in drying rate was also noticed for protein content only that no significant effect in the mean values was noticed at 0.15% (24.69 %) and 0.45% (24.72 %) of foam stabilizer. For vitamin C content, all the mean values were between 1.4 % - 1.49% as the foam stabilizer increased from 0.15 to 0.75 %. Increase in whipping time (3 min to 7 min) caused a progressive increase drying rate (18.9411 g/h to 20.67 g/h) and protein content (24.71 % to 24.72%). However, the vitamin C content did not reduce below 1.4% with increase in whipping time.

Conclusions. Increase in foaming agent (egg white), foam stabilizer (carboxyl methyl cellulose) caused the drying rate and protein content of the foam-mat dried tomato powder to increase to values not below 20 g/h and 24 % respectively. However, the mean vitamin C content reduced but was not less than 1.3 %.

Introduction

Tomato (*Lycopersicum esculentum*) is an important food condiment which belongs to the fruits and vegetable class. It is rich in carotene, vitamins B, ascorbic acid (vitamins C) and other nutrients that are valuable for human growth and health. Tomato is highly perishable in its natural state after harvest due to its high moisture content and high rate of metabolic activities; hence, it is prone to high postharvest losses. In Nigeria, tomatoes are usually produced on a seasonal basis and due to lack of good storage facility, a lot of wastage occurs during the production season and immense scarcity occurs during off seasons. Fresh tomatoes contain 33 % of vitamin C and 3 % of protein per 180 g [1].

Past research has revealed that drying is one of the most practically and economically feasible method of reducing postharvest losses, preventing wastage and prolonging shelf lives of tomato fruits. Also, drying offers significant weight and volume savings, minimizing packaging and transportation costs, and enabling storage of the product at ambient temperature.

Other importance of drying were as reported in [2, 3, 4]. However, a more viable option that can be readily acceptable to the food processing industry is the conversion of tomato paste to powder without any or little change to the quality characteristics via foam-mat drying technology.

The foam-mat drying technology involves drying thin layers of foamed material in heated, un-dehumidified air at atmospheric pressure and it is considerably cheaper than vacuum, freeze and spray drying methods. Before the drying takes place, there is need to first turn the products to be dried into a foamy substance, followed by spreading on mat (flat surface) to form a thin layer. Foam is made up of two phase system having a dispersed phase (usually air) and a continuous phase. The dispersed phase is larger than the continuous phase [5, 6].

A good understanding of the nature of the foams and their physical properties would lead to having a good control over them [7]. Maintenance of the honey comb structure of the foam throughout the period of drying is very important, if not, the purpose of using foam mat method of drying would not be achieved. To ensure this, foam stabilizers such as gelatin, carboxyl methyl cellulose (CMC) and so on are usually added to the material together with foaming agents like egg white or milk. After this, the products are turned to foam via any of the following methods: (i) addition of unlimited amount of air to limited amount of liquid (for example, shaking and whipping); (ii) addition of limited amount of liquid with limited amount of air; and (iii) in-situ bubble development in the liquid [8,5].

Foam stabilizers basically increase the interfacial visco-elasticity of foam lamellae, which subsequently increase the stability of the foam [9]. Xanthan gum as a foam stabilizer is highly adaptable for industrial applications because the temperature of water does not affect its solubility irrespective of the processing temperature [10]. In forming foam, the addition of unlimited amount of air to limited amount of substance to be foamed is popular because of its ease of operation; hence, it is widely used in foam making [11].

One of the most effective ways of reducing postharvest losses in agricultural and food materials is drying. However, prolonged time of drying has the tendency of reducing the nutritional and sensory characteristics of highly perishable produce like tomato. This situation is very common especially when the temperature of drying is high. Converting tomato paste to a foamy substance before drying is a viable option of addressing the aforementioned problems because it will make it to dry faster than the conventional drying process and enhance retention of qualities after drying. Therefore, the objective of this research was to determine the effects of the foaming agent (egg white), foam stabilizer (carboxyl methyl cellulose) and whipping time on drying rate, protein content and vitamin C content of foam-mat dried tomato powder.

Materials and methods

Experimental design. A 3^3 factorial experiment in a Randomized Complete Block Design (RCBD) was used for the study. The factors considered in the experiment were 3 levels each of foaming agent (egg white): 5 %, 10 % and 15 %, foam stabilizer (carboxyl methyl cellulose): 0.15 %, 0.45 % and 0.75 % and whipping time: 3 min, 5 min and 7 min. Each treatment combination was replicated three times, and this made all the experimental runs tested and measured to be 81 in all. The experiment was conducted in the Chemical Engineering Laboratory of University of Ilorin, Ilorin, Nigeria. The average room temperature was about 30˚C and the average relative humidity was not less than 60 % throughout the period of the experiment.

Preparation of samples. Freshly harvested riped tomato fruits ("dan UTC" variety) free from blemish, were procured from a popular market in Ilorin metropolis (Kwara State, Nigeria). They were further graded in order to get better quality for the experiment. After the grading operation, they were washed with clean water to get rid of all external foreign materials. After washing, all the tomatoes were blanched for 30 seconds; the blanching process was done to minimize or stop enzymatic action which would have led to loss of flavor, colour and texture. All the blanched samples were sliced and deseeded with stainless steel knife on a stainless steel tray. After which they passed through the blending process to form tomato paste.

100ml each of the formed tomato paste was then poured into small containers (81 containers). Each container was foamed with varying concentration of egg white (5% 10% and 15%), Carboxyl Methyl Cellulose (CMC) (0.15% 0.45% and 0.75%) according to the experimental treatment combinations. The mixture was then agitated (whipped) to form the foam at whipping time of 3 minutes, 5 minutes and 7 minutes, the 400 W jug-type blender(400 W, model number FPO12A) was used for this process of whipping which was opened at the top to allow the entrance of air to the foam. The digital scale (OHAUS 3001) was used for taking all the weight measurements of this experiment.

Drying procedure. At the end of foam formation, all the samples were spread on flat stainless steel trays (mat) in thin layers (3mm) in preparation for drying in the oven. All the drying operations were carried out in a laboratory air-oven (model MINO50–10G039). A temperature of 70˚C was maintained in the oven for the drying operation of the main experiment. This temperature was in between what was used by [12] and [13] for foam mat drying. Also, the temperature (70˚C) gave better results after using temperatures 70˚C, 75˚C, 80˚C and 85˚C for preliminary experiments in terms of; increased drying rate, good quality of powder and better reconstitution property; this result confirmed what was observed by [12] and [13].The mass of samples on trays were taken on hourly basis in order to determine their drying rates of the drying process. This process of weight measurement continued until the moisture content of samples reduced to an average value of 4.5 % (db) with crispy texture. The average time of drying to achieve this moisture content was approximately 4 hours, however, the control sample took about 8.5 hours to reach 4.5 %(db) moisture content. After the drying process, each sample (dried tomato powder) was immediately scraped from the stainless steel tray and allowed to cool. All cooled samples in small sterilized containers were immediately kept inside desiccators and were taken to the laboratory for quality analysis.

Measurement of output parameters.

Drying rate. The drying rate was estimated using the equation below:

$$d = \frac{d_m}{d_t} = \frac{m_i - m_f}{t} \quad (1)$$

where d is drying rate in g/h;d_m is change in mass sample in g; d_t is change in time in h; m_i is initial mass sample in g; m_f is final mass of sample in g; and t is time in h.

Post-drying qualities. The post-drying qualities of tomato powder were determined using [14] procedures at the Chemistry Laboratory of University of Ilorin, Ilorin, Nigeria. The following post-drying qualities were determined: Protein Content and Vitamin C.

Statistical analysis. All the data obtained from the experiment were subjected to statistical Analysis of Variance (ANOVA) at significant level of ≤ 0.05 in SPSS 16.0 statistical computer software package. A further analysis to compare the means of result among different levels of experimental conditions was also carried out with Duncan's New Multiple Range Test (DNMRT).

Results and discussion

Table 1 presents the result of statistical analysis of variance (ANOVA) of data obtained from the experiment carried out. From the table, foaming agent and whipping time had significant effect on the drying rate with the exception of foam stabilizer at P≤ 0.05. For protein content of the dried sample, only the whipping time had no significant effect. Lastly, all the process conditions had no significant effect on the vitamin C content of the dried sample at P≤ 0.05.The interpretation of the above statement is that all the factors that had significant effect on the output parameters (drying rate, protein content and vitamin C) of the process should be given special attention in this kind of research.

Effect of foaming agent on drying rate, protein content and vitamin C content of foam-mat dried tomato powder. Table 2 shows the effect of foaming agent on drying rate, protein content and vitamin C contents of foam-mat dried tomato powder. From the table, increase in the quantity of foaming agent (from 5 – 10 %) caused a decrease in drying rate (20.63 g/h to 18.57 g/h), however, a further increase in drying rate (10 -15 %) caused the drying rate to increase (from 18.57 g/h to 20.63 g/h). There is no significant difference in the mean values of drying rate for 5 % and 15 % foaming agent. For the protein content, increase in the percentage of foaming agent led to a slight increase in the values of protein content (24.65% to 24.79%); this trend could be attributed to the fact that the foaming agent used (egg white) is usually high in protein. Furthermore, increase in the quantity of foaming agent did not cause the vitamin C content of the dried tomato powder to fall below 1.3 %, however, as the foaming agent increased, the vitamin C content showed a reduction in its values. The result of the quality analysis of foam-mat dried mango pulp showed a significant reduction in ascorbic (vitamin C) with increase in foam thickness [15]. The losses experienced in vitamin C could be due to the heat sensitive nature of vitamins and water soluble nature of vitamin C (i.e. some vitamin C could have escaped along with the moisture during the drying operation). The highest value of protein content (1.55%) was achieved at 5 % foaming agent, although all the mean values were significantly different from each other.

Table 1

Results of the Analysis of Variance (ANOVA) of the effect of process conditions on the drying rate, protein content and vitamin C content of foam-mat dried tomato powder

SV	DF	SS	MS	F	Sig.
	Drying Rate (g/h)				
Foaming Agent	2	25.57	12.79	6.50	0.01*
Foam Stabilizer	2	7.56	3.78	1.92	0.17
Whipping Time (min)	2	14.48	7.24	3.68	0.04*
Error	20	39.36		1.97	
Total	26	10827.85			
	DF	**SS**	**MS**	**F**	**Sig.**
	Protein Content (%)				
Foaming Agent	2	0.09	0.05	31.47	0.00*
Foam Stabilizer	2	0.13	0.01	4.65	0.02*
Whipping Time	2	0.01	0.01	0.40	0.67
Error	20	0.03		0.01	
Total	26	16502.22			
	DF	**SS**	**MS**	**F**	**Sig.**
	Vitamin C content (%)				
Foaming Agent	2	0.15	8.17	309.31	0.09
Foam Stabilizer	2	0.02	0.01	2.76	0.69
Whipping Time	2	0.01	0.01	0.20	0.82
Error	20	0.53		0.03	
Total	26	57.70			

*Significant at P ≤0.05

SV-Sources of Variation; DF-Degree of Freedom; SS-Sum of Squares; MS-Mean Squares; F-variance of group means per mean of within group variances; Sig.-Significant, P- estimated probabilities from experimental data.

Table 2

Effect of foaming agent on drying rate, protein content and vitamin C content of foam-mat dried tomato powder

Foaming Agent (%)	5	10	15
Drying Rate (g/h)	20.63^{a}	18.57^{b}	20.63^{a}
Protein Content (%)	24.65^{a}	24.73^{b}	24.79^{c}
Vitamin C (%)	1.55^{a}	1.44^{a}	1.37^{a}

Means with the same letter are not significantly different from each other at P≤ 0.05

Effect of foam stabilizer on drying rate, protein content and vitamin C content of foam-mat dried tomato powder. Table 3 presents the effect of foam stabilizer on drying rate, protein content and vitamin C content of foam-mat dried tomato powder. From the table it is clearly seen that increase in the percentage of foam stabilizer caused an increase

in drying rate from 19.33 g/h to 20.62 g/h. However, there was no significant difference in the mean values at 0.15 %and 0.75 % foam stabilizer. This clearly showed that the higher the quantity foam stabilizer, the better the structure and durability of the foam. This condition caused a faster escape of moisture during drying, and thus led to higher drying rate. The latter statement was similar to the submission of [9]. The trend in drying rate was also noticed for protein content only that no significant effect in the mean values was noticed at 0.15% (24.6944%) and 0.45% (24.7233%) of foam stabilizer. For vitamin C content, all the mean values were between 1.4 % - 1.49% and they were all insignificant from each other.

Table 3

Effect of foam stabilizer on drying rate, protein content and vitamin C content of foam-mat dried tomato powder

Foam Stabilizer (%)	**0.15**	**0.45**	**0.75**
Drying Rate(g/h)	19.33^{a}	19.88^{b}	20.62^{a}
Protein Content (%)	24.69^{a}	24.72^{a}	24.75^{b}
Vitamin C (%)	1.43^{a}	1.49^{a}	1.44^{a}

Means with the same letter are not significantly different from each other at P≤ 0.05

Effect of whipping time on drying rate, protein content and vitamin C content of foam-mat dried tomato powder. The effect of whipping time on the drying rate and post-drying qualities of foam-mat dried tomato paste is presented in Table 4. The general deduction from the table is that the mean values of all the output parameters were not significantly different from each other with increase in whipping time at $P \leq 0.05$. The aforementioned condition also justified what was noticed on the ANOVA table (Table 1). Specifically, increase in whipping time caused a progressive increase drying rate and protein content. However, the vitamin C content maintained values between 1.42% - 1.48 % with increase in whipping time from 5 min to 7 min.

Table 4

Effect of whipping time on drying rate, protein content and vitamin C content of foam-mat dried tomato powder

Whipping Time (min)	**3**	**5**	**7**
Drying Rate (g/h)	18.94^{a}	20.23^{a}	20.67^{a}
Protein Content (%)	24.72^{a}	24.72^{a}	24.72^{a}
Vitamin C (%)	1.42^{a}	1.48^{a}	1.45^{a}

Means with the same letter are not significantly different from each other at P≤ 0.05

Conclusions

In conclusion, foaming agent had significant effect on drying rate and protein content; while foam stabilizer and whipping time had significant effect on protein content and drying rate respectively of the foam-mat dried tomato powder at $P \leq 0.05$.

Also, increase in foaming agent (egg white), foam stabilizer (carboxyl methyl cellulose) caused the drying rate and protein content of the foam-mat dried tomato powder to increase to values not below 20 g/h and 24 % respectively. However, the mean vitamin C content reduced but was not less than 1.30 % at $P \leq 0.05$.

Furthermore, to get maximum drying rate of 20.67 g/h and maximum protein content of 24.74 % the following combinations of process conditions should be used: foaming agent (15%), foam stabilizer (0.75%) and whipping time (7 min). Also for vitamin C to attain maximum value of 1.47 %, foaming agent should be 5%, form stabilizer- 0.5 % and whipping time should be 5 min.

Lastly, it was generally observed via physical examination that foaming agent at 10% and 15% together with other combinations of form stabilizer and whipping time gave better attractive color of dried tomato powder in terms of deep red and light red. This is in contrast with brown and deep brown colors that were noticed for 5% foaming agent with combinations of other levels of form stabilizer and whipping time.

References

1. GMF, (2015), *The World's healthiest food: Tomatoes*, Available at: http://www.whfoods.com/genpage.php?tname=foodspice&dbid=4, accessed on 16/08/2015.
2. Kendall, P., Dipersio, P. and Sofos, J. (2012), *Drying Vegetables*, Available at: www.ext.colostate.edu/pubs/foodnut/09308html, accessed on 3/4/2104.
3. Troftgruben, J. (1977), *Drying Foods*, Available at: www.aces.uiuc.edu/vista/html, accessed on 3/4/2013.
4. Kiremire, B.T., Musinguzi, E., Kikafunda, J.K. and Lukwago, F.B.(2010), Effects of Vegetable Drying Techniques on Nutrient Content: A Case Study of South Western Uganda,*African Journal of Food, Agriculture, Nutrition and Development (AJFAND)*, 10(5), pp. 2587-2600.
5. German, J.B and Phillips, L. (1994), Protein Interactions in Foams: Protein – Gas Phase Interactions, *Protein Functionality in Food Systems*, N. S. Hettiarachchy and G.R. Zigler, Mercel Dekker Inc, pp. 181–208.
6. Baniel A., Fains A and Popineau Y. (1997), Foaming Properties of Egg Albumen with Bubbling Apparatus Compared with Whipping, *Journal of Food Science*, 62(2), pp. 377-381.
7. Foegeding, E.A., Luck, P.J and Davis, J.P. (2006), Factors Determining the Physical Properties of Protein Foams, *Food Hydrocolloids,* 20(2-3), pp. 284-292.
8. Halling P.J. (1981), Protein-Stabilized Foams and Emulsion, *CRC. Rev. Food Science and Nutrition*, 15(2), pp. 155 – 203.
9. Heller J.P and Kuntamukkula M.S. (1978), Critical Review of the Foam Rheology Literature, *Ind. Chem. Res*, 26(2), pp. 318–325.
10. Becker A., Katzen F., Puhler A and Lelpi L. (1998), Xanthan Gum Biosynthesis and Application: A Biochemical/Genetic Perspective, *Applied Microbiology and Biotechnology*, 50(2), pp. 145-152.

11. Prins, A. (1988), *Principles of Foam Stability: Advances in Food Emulsions and Foams*, *Eds. G. Stainby*, Elsevier Applied Science.
12. Sharada, S. (2013), Studies on Effect of Various Operating Parameters and Foaming Agent – Drying of Fruits and Vegetables, *International Journal of Modern Engineering Research*, 3 (3), pp. 1512-1519.
13. Wilson, R.A.; Kadam, D.M.; Chadba, S and Sharma, M. (2012), Foam Mat Drying Characteristics of Mango Pulp. *International Journal of Food Science and Nutrition Engineering*, 2 (4), pp 63–69.
14. AOAC. (2002), Association of Official Analytical Chemists. *Official Method of Analysis*, Washington D.C.
15. Kandasamy P., Varadharaju N., and Kalemullah S. (2012), Foam-mat Drying of Papaya (Carica Papaya L) Using Glycerol Monostrate as Foaming Agent, *Food Science and Management*, 9, pp. 17–27.