Croat. J. Food Sci. Technol. (2019) 11 (2) 187-194

Croatian Journal of Food Science and Technology
journal homepage: www.ptfos.unios.hr/cjfst/

Original scientific paper

DOI: 10.17508/CJFST.2019.11.2.06

Response surface methodology assessment of osmotic pre-drying and convective dehydration processes on the anti-oxidant property of *Hausa* variety of tomato

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ARTICLE INFO

Article history:
Received: November 21, 2018
Accepted: July 18, 2019

Keywords:
Hausa tomato variety
drying
vitamin C
sugar and honey solution

ABSTRACT

This study was conducted to determine the effect of osmotic pre-drying treatment on the vitamin C content of *Hausa* variety of tomato. The tomatoes used were sliced to a uniform diameter of 10 mm, deseeded and then osmotically pre-treated with sugar and honey solution at different osmotic concentrations (20, 30, 40, 50, 60 °Bx), osmotic time (10, 20, 30, 40 and 50 min) and osmotic temperature (10, 20, 30, 40, 50 °C). Experimental design was done using the Central Composite Design (CCD) methodology of Design Expert software version 6.0.6. Drying of the samples was done at 65 °C in a cabinet dryer operating mainly on convectional heat transfer. Drying process was completed and terminated when the samples reached their equilibrium moisture content between 3-5% after total drying time of 10 hours. The data obtained were analysed statistically using analysis of variance (ANOVA) and regression analysis at $p \leq 0.05$ significance level. The developed model was significant and has goodness of fit with an R^2 value of 71.29% and lack of fit test was insignificant at $p \leq 0.05$. Optimized process conditions for producing the best quality of tomato product with vitamin C content of 22 mg/100 g were 35.43 °Bx osmotic concentration, 11.10 min osmotic time and 23.86 °C osmotic temperature having a desirability function of 1. These conditions were considered to be advantageous as they were more economical, time and energy saving.

Introduction

Tomato is a crop with high yield when grown but termed a short duration crop (Shakara et al., 2005). Over the last decades both fresh and processed tomato products have aroused new scientific interest, due to their high nutritional values most especially their anti-oxidant properties such as vitamin C, lycopene, beta-carotene and phenol which have numerous benefits to the human health (Van et al., 2000; Rao and Agarwal, 1999). Vitamin C is an important and essential nutrient for the human body and considered an index on nutrient quality of food processes (Santos and Silva, 2010). According to USDA data base (2016) a fresh tomato has an average vitamin C content of 14 mg/100 g. An average sized tomato can supply the human body with 40% of the daily recommended allotment of vitamin C. Raw honey has also been found to contain large amounts of compounds such as flavonoids and other polyphenols which may function as antioxidants (Manisha and Mandal, 2011). Antioxidants in tomato have been attributed to decrease the risk of cancer and cardiovascular diseases (Agarwal et al., 2000). According to FAO (2014), Nigeria produces about 2.14 million metric tonnes of tomato fruits annually but sadly, approximately 750,000 tonnes of them are being wasted during their surplus season. This can be attributed to poor postharvest handling technique, which is predominant in

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every region of Nigeria. Hence, it is important for tomato to be processed as this would ease transportation and prolong the fruit's shelf-life over a long period before consumption, thereby reducing the wastage incurred. According to And and Barret (2006), not all fresh tomatoes can be consumed at the time of harvest. Preservation provides a larger market, allowing consumers to buy the product on a year-round basis. *Hausa* variety is a popular tomato variety widely consumed in Nigeria and known for its high nutritional qualities and low moisture content among other varieties. *Hausa* variety of tomato in Nigeria has been identified by Swofford and Olsen (1990) and Ezekiel et al. (2011). Drying technology is suitable for processing tomato fruits in Nigeria as it is ideal for developing economies. However, it is important to use pre-drying treatment technique as process parameter that would maintain and as well improve the nutritional and sensorial qualities of tomato during drying. As studied by Tunde-Akintunde et al. (2008), Iyanda et al. (2014) and Idah and Obajemihi (2014), the air temperature used during drying process can greatly influence the retention of vitamin C content of fruits and vegetables as it causes degradation of the compound. The aim of the study was to investigate the effect of osmotic pre-drying treatment process on the retention of vitamin C content of *Hausa* variety of tomato.

Material and methods

Materials

Healthy, fresh, firm and ripe tomato, *Hausa* (local breed) variety, shown in Figure 1, was purchased from a farmer in Oteh area, a suburb of Ilorin, Kwara State, Nigeria. Grade A natural honey which was characterized according to Fasasi (2012) was purchased from the Apiary unit of the University of Ilorin, Ilorin, Nigeria. Sugar used was purchased from AMB, local provision store in Oke-odo, Ilorin. Other materials used include wire rubber net, stainless steel knife and pan, gloves, distilled water, and osmotic bowls.

Fig 1. The tomato samples during sorting

Equipment

Weight measurement of samples was done with a digital weighing scale (Model: WH-B06, sensitivity ± 0.01g by WEIHENG, China). 1000 mL volumetric flask and 500 mL beaker were used to measure volume of the osmotic solution. A table top refractometer (Model: M10481, by ABBE MARK II, USA) was used for the determination of osmotic brix concentration. Water bath (Model: W20M-2, by AL-TAR, USA) was used for maintaining constant osmotic temperature above ambient (room) temperature during pre-drying treatment. A Refrigerator (Model: HR-195B, by THERMOCOOL, Nigeria) was used to maintain constant osmotic temperature below ambient (room) temperature. An Infra-red moisture meter (Model: LSC-50, by NAPCO, China) was used for the determination of samples' moisture contents.
An electric cabinet dryer was used for drying the samples and digital thermo-hygrometer (Model: QC4114, by ACURITE, China) was used to monitor drying air temperature and relative humidity in the drying chamber during the course of the experiment. Electricity generating set (Model: TG2700, Tiger, China) served as the alternative power source. Laboratory stop watch (Model: 501, by NAHITA, China) was used to monitor osmotic and drying time. Dried samples were cooled and stored in a laboratory desiccator for 2 h before nutritional analysis was conducted on them.

Experimental procedure

The experiment was carried out in the food processing laboratory of the department of Food Engineering, University of Ilorin, Kwara State, under ambient temperature of 29 °C and relative humidity of 93%. The tomatoes were first washed under a running tap and sliced into a uniform thickness of 10 mm to form circular shapes, using a stainless steel knife. After slicing, the tomatoes were osmotically pre-treated in a mixture of sugar and honey solution of various osmotic concentrations of 20, 30, 40, 50 and 60 °Bx (prepared in the ratio of sugar:honey:water (1:2:6.6, 1:2:3.7, 1:2:1.9, 1:2:0.84 and 1:2:0.1, respectively)) and osmotic temperatures of 10, 20, 30, 40 and 50 °C for 10, 20, 30, 40, and 50 min osmotic time. Thereafter, the samples were withdrawn from the solutions and drained for 10 min on wire gauze and dried at temperature of 65 °C in a cabinet dryer. During the drying the samples were weighed every 15 min for the first hour, 30 min for the next 4 h and each hour for the remaining drying time until weight becomes constant and there is no appreciable weight loss.

Brix preparation

The mixture of sugar and honey solution used for this experiment was prepared with the use of standard equipment.

Table 1. Coded values and corresponding actual values used in CCD design

Input Parameters	Coded Levels				
	-1	-0.5	0	0.5	1
Osmotic conc. (°Bx)	20	30	40	50	60
Osmotic time (min)	10	20	30	40	50
Osmotic temp. (°C)	10	20	30	40	50

Experimental design

The experiment was designed with Design expert 6.0.6 software, the Central Composite Design (CCD) of response surface methodology (RSM) was used. Experimental input parameters include osmotic solution concentration (A), osmotic time (B) and osmotic temperature (C), the coded values of the experimental design were interpreted for each input parameter as found in Table 1. The experimental design had 15 runs altogether as shown in Table 2 and the runs were made in triplicates.

Determination of drying time

The drying time of the samples in the dryer was monitored and recorded with the use of a digital laboratory stopwatch.

Determination of moisture content

Moisture content of samples was analysed based on the wet basis and it was expressed mathematically as;

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

where: W_1 =Initial weight of sample (g); W_2 =Final weight of sample (g)

Determination of vitamin C content

Analysis of the vitamin C content of the samples was done according to AOAC (1990) technique.

Statistical analysis

The experimental data obtained as the output for each sample were entered into SPSS software (Version 20, UK) and design interface of the Design expert software version 6.0.6 and were evaluated statistically using analysis of variance (ANOVA) and regression analysis at $p \leq 0.05$ significance level.

Results and discussion

Analysis of fresh Hausa tomato sample

Fresh tomato sample of *Hausa* variety was analysed in the chemistry laboratory of industrial chemistry department, university of Ilorin and was found to have an initial moisture content of 85.03% and vitamin C content of 18.04 mg/100 g.

Effect of osmotic concentration, osmotic time and their interaction on vitamin C content of tomato

As shown in Figure 2, the interactive effect of osmotic time and osmotic concentration on the retention of vitamin C content produces a hyperbolic paraboloid curve, the 3-D curve deflected downwards gently towards the x-axis (osmotic time) and upwards sharply towards the y-axis (osmotic concentration), which dictates the retention of vitamin C content on the z-axis. The retention of vitamin C content as affected by osmotic concentration follows a concave curve, which increased gently from 4 to 14 mg/100 g; when the concentration of the osmotic solution rises from 20 °Bx to 40 °Bx, respectively. Thereafter it decreases down the slope gently from 40 °Bx to 60 °Bx with the vitamin C content value dropped from 14 to 4 mg/100 g, respectively. These showed that maximum retention of vitamin C content of 14 mg/100 g occurred at 40 °Bx. These results show similarities with the findings of Alabi et al. (2016) on the vitamin C content of osmotically pretreated onion with NaCl solution, whereby the highest retention of vitamin C content was achieved at the mid-point of the concentration used, suggesting that moderate concentration was desirable for the retention of vitamin C content of tomato during drying. On the other hand, the retention of vitamin C content as affected by osmotic time follows a curve with convex trend, which dropped sharply with values of 14 to 1 mg/100 g from 50 min to 30 min and increased sharply with values of 1 to 14 mg/100 g from 30 min to 10 min, respectively. Therefore, minimum retention of vitamin C content of tomato slices after drying was influenced by 30 min osmotic time, suggesting that 10 min osmotic time is desirable to retain the vitamin C content of tomato, as it saves time. These results, however, show disparities with the findings of Alabi et al. (2016) as retention of the vitamin C content tends to increase with increase in osmotic duration. The result of the ANOVA shown in Table 3 revealed that, statistically, the linear effect of osmotic concentration (A), osmotic time (B) and their interactive effect (AB) were not significant on the retention of vitamin C content of tomato at $p \leq 0.05$, but their quadratic effect A^2 and B^2 were significant on the retention of vitamin C content at $p \leq 0.05$.

Table 2. Results of experiments in central composite design

Run	Osmotic conc. (°Bx)	Osmotic time (min)	Osmotic temp. (°C)	Vitamin C (mg/100 g)
1	60	50	10	12.08±0.006[f]
2	60	10	50	9.40±0.06[h]
3	40	30	20	14.38±0.044[c]
4	30	30	30	10.40±0.17[g]
5	20	10	10	14.16±0.01[c]
6	40	30	30	10.66±0.39[g]
7	60	50	50	8.91±0.07[h]
8	20	50	50	8.42±0.01[i]
9	40	40	30	16.08±0.08[a]
10	60	10	10	15.16±0.18[b]
11	40	20	30	13.17±0.01[d]
12	20	10	50	7.03±0.02[j]
13	40	30	40	8.07±0.06[i]
14	50	30	30	6.80±0.80[j]
15	20	50	10	12.66±0.22[e]

*Superscript a-h with the same letter in the column were not significantly different from one another at $p \leq 0.05$

The 3-D plot showing the interaction existing between osmotic concentration and osmotic temperature is shown in Figure 3. The curve is parabolic concave in nature with a fairly regular pattern all through. The osmotic time on x-axis of the graph shows an inclined plane which shows that increase in osmotic temperature does not really depicts any significant effect on the retention of the vitamin C content, this is in agreement with the findings of Alabi et al. (2016). However, the increase in osmotic temperature from 10 to 50 °C led to slight decrease in the vitamin C content retention from 9 to 7 mg/100 g. This is in agreement with the findings of Sahin et al. (2011) and Sablani et al. (2006) that increase in process temperature leads to the decrease in vitamin C content retention. Therefore, the pre-treatment done in a refrigerator to maintain an osmotic temperature of 10 °C is desirable and better than those done under temperatures greater than the ambient. On the other hand, the increase in osmotic concentration from 20 °Bx to 40 °Bx led to an increase in the retention of the vitamin C content and decreases thereafter. However, statistically, as shown in Table 3, the linear effect of osmotic temperature was significant on the retention of vitamin C content of tomato but its interaction with osmotic concentration was not significant at $p \leq 0.05$. This is not in agreement with the findings of Alabi et al. (2016).

Figure 4 shows the interactive effect of osmotic temperature and osmotic time, the surface response produced a 3-D plot with a curve that was parabolic convex in nature with steep slope at one edge and gentle at the other. The surface was curved upwards towards the x-axis and downwards towards the y-axis. The graph showed that osmotic temperature variation does not really change the retention of vitamin C content, as the response surface formed a straight line, which was horizontal. Meanwhile the variation of osmotic time reveals that it affects the retention of vitamin C content as it forms a convex curve.

Process model

There was a need to develop a model equation prior to the optimization procedure. Table 4 shows the statistical parameters derived from the model. The model developed was significant and described the process satisfactorily. Figure 5 shows the predicted values versus the experimental values which were close. In Table 4, R^2 and $R^2_{Adj.}$ were considerably high and in reasonable agreement with the $R^2_{Pred.}$ value. The Predicted Sum of Square (PRESS) value was considerably low, the model was supplied with adequate signal and noise was negligible since adequate precision value of 6.932 was sufficient enough, which was greater than 4 as recommended by Stat-Ease (2000) and the Prob.>F for the lack of fit was not significant. All these suggest that the model developed has goodness of fit.

Model equation

$$\text{Vitamin C content} = 11.20 + 0.18A - 0.26B - 2.76C - 11.65A^2 + 12.45B^2 - 1.01C^2 - AB + 0.31AC + 0.69BC \quad (2)$$

(in terms of coded factor)

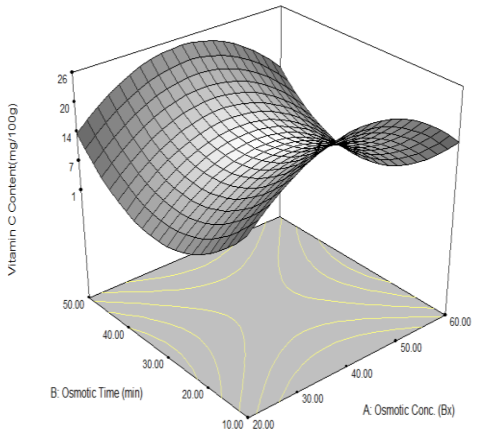

Fig 2. Effect of osmotic time and osmotic concentration on vitamin C content

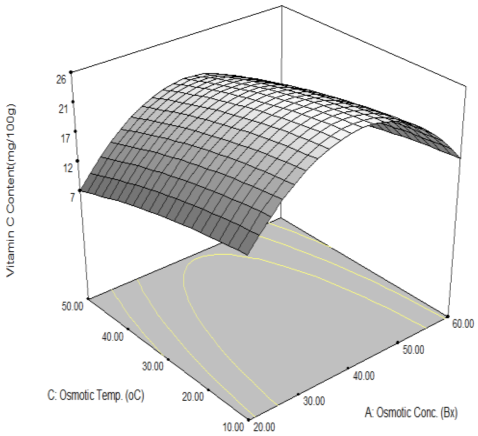

Fig 3. Effect of osmotic temperature and osmotic concentration on vitamin C

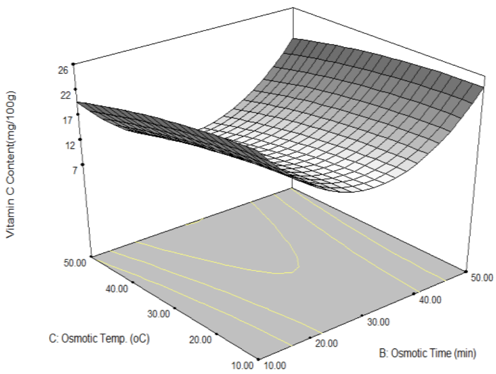

Fig 4. Effects of osmotic temperature and osmotic time on vitamin C content

Table 3. Analysis of variance (ANOVA) for vitamin C content

Source	Sum of Squares	DF	Mean Square	F Value	Prob > F
Model	108.19	9	12.02	3.45	0.0335*
A	0.26	1	0.26	0.075	0.7899**
B	0.58	1	0.58	0.17	0.6927**
C	64.69	1	64.69	18.55	0.0015*
A^2	25.32	1	25.32	7.26	0.0225*
B^2	28.94	1	28.94	8.30	0.0164*
C^2	0.19	1	0.19	0.054	0.8204**
AB	1.49	1	1.49	0.43	0.5284**
AC	0.75	1	0.75	0.22	0.6527**
BC	3.77	1	3.77	1.08	0.3231**
Residual	34.87	10	3.49		
Lack of Fit	20.73	5	4.15	1.47	0.3426**
Pure Error	14.15	5	2.83		
Cor. Total	143.06	19			

*Significant and ** Not Significant at $p \leq 0.05$.

Table 4. Multiple regression statistics for checking adequacy of developed model equation

Statistics	Vitamin C content (mg/100 g)
R^2	0.713
$R^2_{Adj.}$	0.610
$R^2_{Pred.}$	0.422
PRESS	82.70
Model F-value	6.95
Model P-value (Prob.>F)	0.0019*
Adequate Precision	6.93
Coeff. of Variation	15.41
Lack of Fit (Prob.>F)	0.50

* Model was Significant at $p \leq 0.05$.

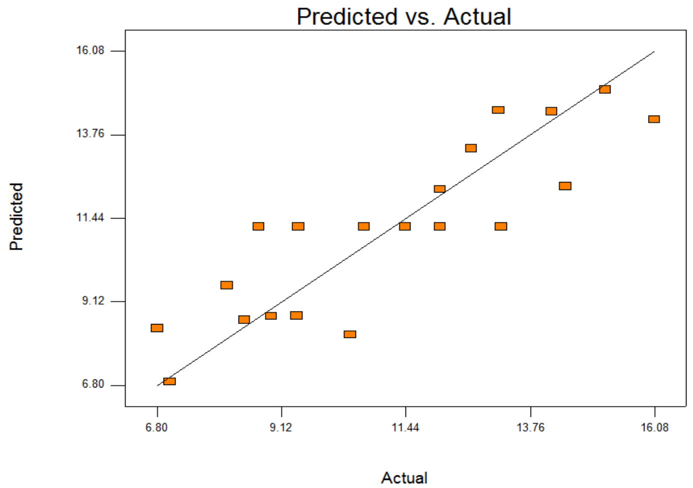

Fig 5. Predicted vs. actual values for the retention of vitamin C content

Table 5. Settings done for numerical optimization on design expert software

Name	Goal	Lower Limit	Upper Limit	Importance
Osmotic conc. (°Bx)	is in range	20	60	3
Osmotic time (min)	is in range	10	50	3
Osmotic temp. (°C)	is in range	10	50	3
Vitamin C Content (mg/100 g)	maximize	6.8	16.08	5

Table 6. Optimization process conditions for optimum yield of vitamin C content

No.	Osmotic Conc. (°Bx)	Osmotic Time (min)	Osmotic Temp. (°C)	VitaminC Content (mg/100 g)	Desirability	Remarks
1	35.43	11.10	23.86	22	1.000	Selected
2	45.75	14.63	12.56	20	1.000	
3	32.80	46.02	25.83	18	1.000	
4	38.85	43.59	19.53	18	1.000	
5	38.74	16.67	27.24	17	1.000	

Process optimization

The process parameters were optimized to achieve combination of process conditions required for the best retention of vitamin C content of dried tomato. This was done to ascertain the process condition that favoured the retention of vitamin C content during dehydration process of the sample in a cabinet dryer at a temperature of 65 °C. The input and output parameters were set on the application as indicated in Table 5. The goal of the optimization process was to optimize the retention of vitamin C content and its level of importance set at the highest. The optimization process produced 5 solutions as shown in Table 6. It was obeserved that all the solutions had desirability functions of 1 which were good. According to Obajemihi et al. (2017), the closer the desirabity functions to 1 the better the optimization result . Solution number one (1) was selected since it produced a response with the highest retention of vitamin C content after the drying process. Therefore, the best retention of vitamin C content 22 mg/100 g, was obtained by immersing tomato slices in sugar and honey solution at 35.43 °Bx osmotic concentration, 11.10 min osmotic time and 23.86 °C osmotic temperature.

Conclusion

The use of sugar and honey solution with varied process conditions affects the retention of vitamin C content of tomato. Osmotic concentration of 40 °Bx was desirable among others for the retention of 14 mg/100 g vitamin C content of *Hausa* variety of tomato, therefore moderate osmotic concentration was good. Osmotic temperature was significant on the retention of vitamin C content, conduction of pre-drying treatment at a temperature below ambient (29 °C) was desirable for the retention of vitamin C content of *Hausa* variety. Prolonged immersion of samples in osmotic solution does not favour the retention of vitamin C content of the samples. Therefore, osmotic time of 10 min was good and time saving. Model developed was significant and adequately described the process which had an R^2 value of 0.7129 and Lack of fit test was insignificant at $p \leq 0.05$. Optimized process conditions for producing the best tomato product with a vitamin C content of 22 mg/100 g were 35.43 °Bx osmotic concentration, 11.10 min osmotic time and 23.86 °C osmotic temperature having a desirability function of 1. These conditions were considered to be more economical, time and energy saving.

References

Agarwal, S., Rao, A. V. (2000): Tomato lycopene and its role in human health and chronic diseases. *CMAJ.* 163(6), 739-744.

And, G. L., Barret, D.M. (2006): Influence of pre-drying treatment on and safety of sundried tomatoes part II, effects of storage on nutritional and sensory quality of sundried tomatoes pre-treated with sulphur, sodium metabisulfite or salt. *J. of Food Sci. Institute of Food Technol.* 71(1), S24 – S31. https://doi.org/10.1111/j.1365-2621.2006.tb12401.x

Alabi, K.P., Olaniyan, A.M., Odewole, M.M. (2016): Characteristics of onion under different process pretreatments and different drying conditions. *J of Food Process and Technol.* 7(555), 2 http://dox.doi.org/10.4172/2157-7110.1000555.

AOAC (1990): Official methods of analysis of the association of official analyticalchemist (15th edition). Arlington, Virginia.

Ezekiel, C.N., Nwangburka, C.C., Ajibade, O.A., Odebode, A.C. (2011): Genetic diversity in 14 tomatoes (*Lycoperison esculentum Mill*) varieties in Nigerian markets by RAPD-PCR technique. *Afr. J. of Biotechnol.* 10 (25), 4961-4967.

Fasasi, K.A. (2012): Physicochemical attributes of Nigerian natural honey from honeybees (*Apis mellifera adansonii*) (Hymenoptera: Apidae) and its shelf life in storage at room temperature. *Pak. J. of Biological Sci.* 15(21), 1027-1033. https://doi.org/10.3923/pjbs.2012.1027.1033.

FAO, Food and Agricultural Organization of the United Nations (2014): FAOSTAT Online database (Available: http://faostat.fao.org/.accessed Dec. 2018.

Idah, P.A., Obajemihi, O.I. (2014): Effects of osmotic pre-drying treatment, duration and drying temperature on some nutritional values of tomato fruit. *Academic Research Int.* 5(2), 119.

Iyanda, R.A., Adeboye, O.A., Yusuf, K.A. (2014): Effects of pre-treatment and temperature on quality and drying rate of tomatoes. *Analele Universitatii'Eftimie Murgu* 21(1), 132-145.

Mandal, M. D., Mandal, S. (2011): Honey: its medicinal property and antibacterial activity. *Asian Pacific J. of tropical biomedicine 1*(2), 154-60. https://doi.org/10.1016/S2221-1691(11)60016-6.

Obajemihi, O.I., Sunmonu, M.O., Odewole, M.M., Adeboye, O.A., Omoleyomi, B.D. (2017): Empirical modelling and optimization of drying rate and quality attributes of tomato using response surface methodology. *Fuoye J. of Pure and Applied Sci.* 2(1), 260-174.

Sablani, S.S. (2006): Drying of fruits and vegetables: retention of nutritional/ functional quality. *Drying Technol*. 24, 428–432. https://doi.org/10.1080/07373930600558904

Santos, P.H.S., Silva, M.A. (2008): Retention of Vitamin C in Drying Processes of Fruits and Vegetables - A Review. *Drying Technol.*. 26(12), 1421 – 1437. https://doi.org/10.1080/07373930802458911.

Shakara. N., Joep Van, L.H., Marja, G., Martin, H., Barbara, V.D. (2005): Cultivation of tomato production, processing and marketing. Agromisa foundation and CTA, Wageningen, Agrodok 17.

Stat-Ease (2000). Design-Expert Software.Version 6 User's Guide. Available on www.statease.com.

Swofford, D.L., Olsen, G.J.. Hillis, D.M., Mortiz, C. (1990): Phylogenetic reconstruction, in: molecular systematics. (2nd Eds.). Sinauer Associates, Sunderland.

Tunde-Akintunde, T.Y. (2008): Effect of soaking water temperature and time on some rehydration characteristics and nutrient loss in dried bell pepper. *Agricultural Engineering International: the CIGR Ejournal*. Manuscript FP 08 013. X .

United States Department of Agriculture USDA (2016): National nutrient database for standard reference.

Van den Berg, H., Faulks, R., Fernando, G.H., Hirschberg, J., Olmedilla, B., Southon., Sthal, W. (2000): The potential for the improvement of carotenoid levels in foods and the likely systemic effects. *J. of Sci. of Food and Agric*. 80, 880-912. https://doi.org/10.1002/(SICI)1097-0010(20000515)80:7<880::AID-JSFA646>3.0.CO;2-1