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Optimisation of osmotic dehydration of tomato (*Solanum lycopersicum)*

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ABSTRACT: Optimisation of osmotic dehydration of tomato (*Solanum lycopersicum*) using Response Surface Methodology (RSM) was carried out in this study. The effects of three factors namely, NaCl solution, dehydration time and dehydrating temperature on the lycopene content of dehydrated tomato were investigated. A total of 17 experimental runs were conducted. The Box-Behnken design of RSM was employed and the best model obtained was two-factor interaction (2FI) polynomial. The analysis of variance (ANOVA) test showed that the effect of model terms (NaCl, dehydration time and dehydrating temperature) on the lycopene content as well as the model were significant (Pd"0.05). The optimum factors for the osmotic dehydration of tomato were obtained at 40% NaCl, 30 minutes dehydration time and 30°C dehydrating temperature, which gave lycopene content of 0.0141 mg/100 g at the optimum conditions. In contrast, fresh tomato had lycopene content of 0.0165 mg/100 g while the control, cabinet dried tomato had lycopene content 0.0148 mg/100 g. The R^2 and R^2_{adj} values of 0.9518 and 0.9229 respectively indicated that the regression model was good.

Keywords: Optimisation, osmotic dehydration, lycopene, tomato, response surface methodology.

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INTRODUCTION

The word tomato may be referred to the plant (*Solanum lycopersicom*) or the edible, typically red, fruit which it bears Tomato. Tomato is a pulpy, juicy red fruit used as a vegetable. It is consumed in diverse ways including raw, as an ingredient in many dishes and sauces, and in drinks. It is also as raw material in salads, processed into ketchup or tomato soup. Unripe green tomatoes can also be breaded and fried, used to make salsa, or pickled. Tomato juice is sold as drink and is used in cocktails such as the Bloody Mary. Tomatoes are often picked unripe and ripened in storage with ethylene, for unripe tomato and film. Tomato is best stored at room temperature and tends to lose flavor if refrigerated (Maul *et al.,* 2000). Tomatoes that are yet ripe are optimally stored at room temperature uncovered, out of direct sunlight until ripe therefore, having shelf life of three to four days. Tomatoes are high in vitamin A, vitamin C, calcium and potassium (Aviram, *et al*., 1999).

Lycopene is the pigment principally responsible for the characteristic deep-red colour of ripe tomato fruits and tomato products. It has attracted attention due to its biological and physicochemical properties, especially related to its effects as a natural antioxidant. Tomatoes and related tomato products are also considered important source of carotenoids in the human diet. Undesirable degradation of lycopene does not only affect the sensory quality of the final

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product, but also the health benefit of tomato-based foods for the human body. Owning to their lipophilic nature, lycopene and other carotenoids are found to concentrate in low-density and very-low-density lipoprotein fractions of the serum (Clinton, 1998; Parthasarathy, *et al*., 1992). A major claim for lycopene's benefits is in the prevention and treatment of cancers of the lung, prostate, stomach, bladder, cervix, skin, mouth, pancreas, breast, colon, rectum, bone health, osteoporosis. It is believed to prevent brain tumors and especially prostate (Peters *et al.*, 2007).

Osmotic dehydration in fruits and vegetable is a preparation step to further processing of fruits and vegetables since they contain about 70% moisture content), involving simultaneous transient moisture loss and solid gain when immersing in osmotic solutions, resulting in partial drying and improving the overall quality of food products (fruits and vegetables). The basic principles influencing osmotic dehydration are temperature, concentration, type and consistency of osmotic solution, the size and geometry of the material, the solution-to-materials mass ratio and, to a certain level, agitation of the solution (Rastogi, *et al*.,2005). Response Surface Methodology (RSM) is a statistical method used to optimize. It is also a powerful tool for the optimization of chemical, biological and industrialization processes.

This work studied the osmotic dehydration of tomatoes by varying the NaCl solution concentration, dehydration temperature and time using a Box-Behnken model of Response Surface Methodology) and compared the lycopene content of cabinet dried tomato and osmotic-dehydrated tomato samples

MATERIALS AND METHOD

The fresh tomatoes, oblong shaped "Kerewa" variety were purchased from Sabo Market in Akure, Ondo State.

Experimental design

In order to optimize the Box-Behnken experimental design, a three-level-three factor Box-Behnken was employed for this study, which generated 17 experimental runs. The factors investigated in this study were percentage NaCl used (%), dehydrating temperature (^oC), and dehydration time (min). The coded and uncoded factors (A, B, C), and levels used are shown in Table 1.

Osmotic dehydration of tomato

Ripe tomato (200 fruits of Kerewa variety) obtained from Sabo Market in Akure were sorted visually for colour (completely red), size (average of 4cm in length and 2cm in diameter) and with no physical damage. The tomatoes were washed and drained. As the tomato waxy skin can have high resistance to mass transfer, therefore, the fruits were perforated with needle (about 1mm of diameter to pin hole density of 16 holes/cm^2), according to Shi *et al.* (1997). This insertion with pins was used instead of slicing which can leach out the tomato pigments (lycopene compound) into the solution.

Table 1: Factors and their Levels for Box-Behnken Design for Lycopene content

Variable	Symbol	Coded Levels		
		-1	0	1
Nacl A (%)	X_1	20	40	60
Dehydration time (min)	X_2	30	60	90
Dehydration temperature(^oC)	X_3	30	50	70

Table 2: Reaction Conditions (Nacl, Dehydration Time, and Dehydration Temperature) for Determination of the Lycopene Content

Run	NaCl (%) (A)	Dehydration Time (Min) (B)	Dehydration Temperature (C) (^{o}C)
1	20.00	60.00	30.00
2	40.00	60.00	50.00
3	20.00	30.00	50.00
4	60.00	90.00	50.00
5	40.00	60.00	50.00
6	40.00	60.00	50.00
7	40.00	90.00	70.00
8	40.00	30.00	70.00
9	20.00	90.00	50.00
10	40.00	90.00	30.00
11	40.00	60.00	50.00
12	40.00	30.00	30.00
13	60.00	60.00	70.00
14	60.00	30.00	50.00
15	20.00	60.00	70.00
16	60.00	60.00	30.00
17	40.00	60.00	50.00

The tomatoes were prepared in four fruits per sample for the 17 experimental runs as shown in Table 2. Each sample of the 17 experimental runs was replicated giving total samples of 104 tomato fruits for osmotic dehydration. In comparison, 2 tomato samples were used for only cabinet drying while another 2 fresh tomato samples were used as a control, making 30 samples altogether.

The samples were removed from the solution at the completion of each experiment run using the conditions specified in Table 2. It was drained and excess of solution at the surface was removed with absorbent paper. The twenty six samples of osmo-dehydrated tomato fruits samples were all sliced and further subjected to conventional drying method (cabinet drying) at 65^{0}C for 14 hours to obtain dried tomato slices. The dried tomato slices samples were analyzed in order to know the effect of osmotic dehydration of the various treatment on lycopene content of the tomatoes using Spectrophotometer AJ-1C03

Determination of lycopene content of tomato (Manuals of food analysis and quality control, 2000)

Tomato sample (1g) were cut into pieces and ground in mortar containing some acid-washed-sand. A small quantity of 85 % acetone was

added and mixed, and then decanted into a 100 cm^3 separating funnel labeled, 'A'. It was then ground again and rinsed with acetone and decanted into the same separating funnel (A). The process was repeated until the ground tomato became white in colours. Small quantity of petroleum ether (b.p. 40-60 °C) was added into the separating funnel, followed by small quantity of water. It was well shaken and allowed to settle.

The bottom layer (water/acetone) was removed into another separating funnel, labeled, 'B'. Small quantity of petroleum ether was added to funnel 'B', while small quantity of water was added to funnel 'A', to wash and separate impurities from the sample. They were both allowed to settle with the bottom layer removed. In case of 'A', water layer were retained while for 'B', it was discarded. Petroleum ether layer of 'B' was added to that of 'A'. The water/acetone layer of 'B' was returned into the separating funnel (B) and some more petroleum ether added. Also, small quantity of water was added to 'A', shaken very well, allowed to settle and separated as above. The process was repeated until no colour appeared in the petroleum ether layer in 'B' and none in water layer of 'A'. The 'washed' petroleum layer of 'A' was transferred to 500 cm^3 volumetric flask and made up to 100 cm^3. The optical density (absorbance) of the extract was read with Spectrophotometer AJ-1C03 at 503nm. The lycopene content was calculated as:

$$Lycopene\ content\ \frac{mg}{100}gm = \frac{3.1206 \times OD\ of\ sample \times volume\ made\ up \times dilution \times 100}{wt\ of\ sample \times 1000} \quad \text{..... (1)}$$

Statistical Analysis

The data obtained in the experiments (Table 2) were analyzed using response surface methodology, so as to fit the quadratic polynomial equation generated by the Design-Expert software version 8.0.3.1 (Stat-Ease Inc., Minneapolis, USA). In order to correlate the response variable to the independent variables, multiple regressions was used to fit the coefficient of the polynomial model of the response. The quality of the fit of the model was evaluated using analysis of variance (ANOVA). The fitted quadratic response model is as described by the equation.

$$Y = b_o + \sum_{i=1}^{k} b_i X_i + \sum_{i=1}^{k} b_{ij} X_i^2 + \sum_{i_{1<j}}^{k} \sum_{j}^{k} b_i X_i X_j + e \quad \text{.....(2)}$$

Y is response factor (Lycopene content), i and j denote linear and quadratic coefficients, respectively. b_o is the intercept, b_i is the first order model coefficient, k is the number of factors and e is the random error.

RESULTS AND DISCUSSION

The result showing the effect of NaCl, dehydration time, and temperature (variables) on the lycopene content (response) using response surface methodology is shown in Figures 1 to 3. The optimum lycopene content of 0.0141 mg/100 g was obtained at 40 % NaCl, 30 mins and 30 °C for the osmo-dehydrated tomatoes. The least lycopene content of 0.0069 mg/100 g was obtained at 40 % NaCl, 90 mins dehydration time and 70 °C. In contrast, fresh tomato had lycopene content of 0.0165 mg/100g while tomato dried using cabinet dryer had osmotic content of 0.014 mg/100 g (Table 3).

It was observed that the higher the dehydration temperature and dehydration time of osmotic dehydration the more the leaching out of the lycopene content into NaCl solution while the lower the dehydration temperature and dehydration time, the higher the lycopene content retention. This is in agreement with the

Table 3: Lycopene Content Values for Control Samples

Control	Lycopene content (mg)
Fresh raw tomato	0.0165
Cabinet dried tomato sample	0.0148
Optimized osmotic dehydration sample	0.0141

work of Aboushita, *et al*., (1997) who reported that high temperatures or long drying times in conventional air drying can cause serious damage to product flavor, colour, and nutrient and also reduce the rehydration capacity. Ertekin and Sultanoglu (2000) also reported that osmotic dehydrating is effective at relatively low temperature with minimal damage to colour and texture, but temperature above 45°C can lead to enzymatic browning and flavor deterioration.

The osmo-dehydrated tomato had lower lycopene content in contrast to that of cabinet drying. The osmo-dehydrated tomato nevertheless will however have additional advantages such as retention of nutritional contents over cabinet-dried tomato. The 3D plot (Figures 1 to 3) showed the effect of the variables on the lycopene content for the osmo-dehydrated tomato. Fig. 1 showed the effect of dehydration time and NaCl on the lycopene content while keeping the temperature constant. The highest lycopene content value was obtained at the lowest values of dehydration time and NaCl. As the values of dehydration time and NaCl increases, the lycopene content reduces. The effect of NaCl is not as significant as that of dehydration time. This is further buttressed in Table 4 where the p-value of NaCl is 0.0358, which is greater than the p-value of the duo of temperature and dehydration time, both less than 0.0001.

In addition, the model used (2F1) was significant for the analysis since it has p-value less than 0.0001. Interactive model terms, AB and AC were also significant with the p-value less than 0.005. Model term AC was not significant with p-value

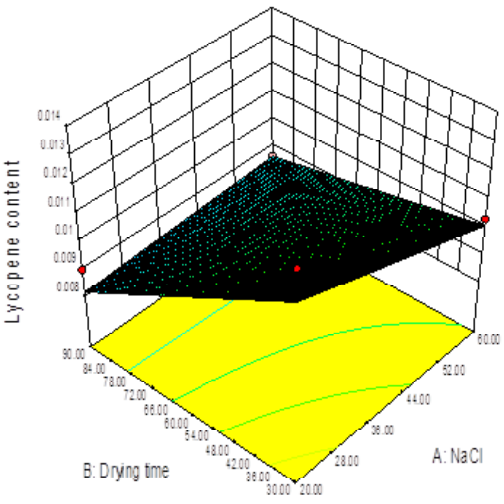

Fig. 1: 3D plot showing the effect of dehydration time and NaCl on lycopene content

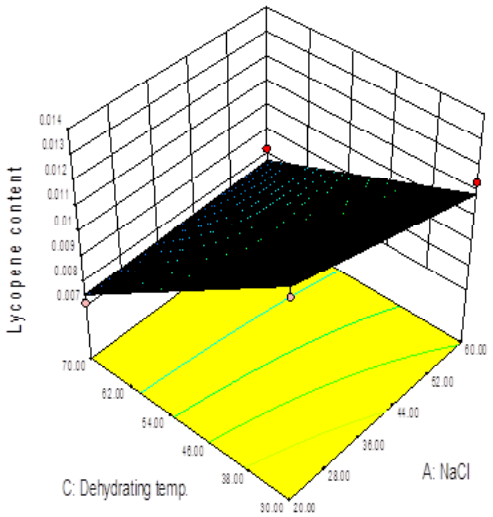

Fig. 2: 3D plot showing the effect of dehydration temperature and NaCl on lycopene content

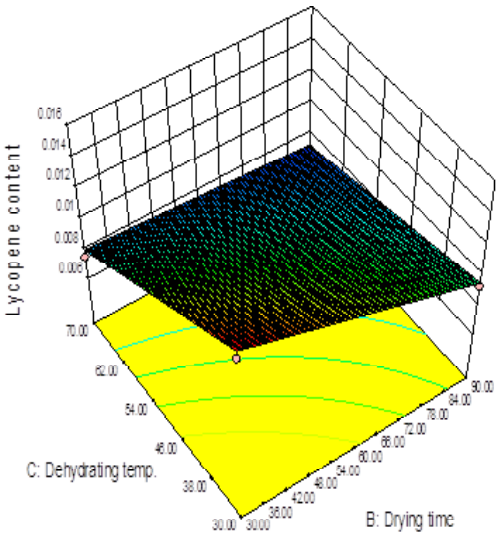

Fig. 3: 3D plot showing the effect of dehydration time and dehydrating temperature on lycopene content

greater than 0.005. The effect of NaCl and Temperature on lycopene content is shown in Fig. 2 while the effect of temperature and dehydration time on the osmotic content is shown in Fig 3 where highest lycopene content at the lowest variables values (40% NaCl, 30 minutes dehydration time and 30°C dehydrating temperature) were obtained.

The analysis of variance (ANOVA) (Table 4) showed that the effect of model terms (NaCl, dehydration time and dehydrating temperature) on the lycopene content as well as the model were significant ($P<0.05$). Quadratic terms (AB and BC) were also significant ($P<0.05$). the model is quadratic

Table 4: ANOVA Table for 2FI Model Osmo-dehydrated Tomato

Source	Sum of squares	df	Mean square	F value	P-value prob> f
Model	6.724 E-005	6	1.121E-005	32.92	<0.0001
A-Nacl	2.000E-006	1	2.000E-006	5.88	0.0358
B-Dehydration time	1.711E-005	1	1.711E-005	50.27	<0.0001
C-Dehydration temperature	4.005E-005	1	4. 005E-005	117.67	<0.0001
AB	2.102E-006	1	2.102E-006	6.18	0.0322
AC	1.563E-006	1	1.563E-006	4.59	0.0578
BC	4.410E-006	1	4.410E-006	12.96	0.0049
Lack of Fit	3.404E-006	6	5. 673E-007		

*df = degree of freedom

The final equations showing the effect of the variables on lycopene content is shown (equation 3)

$$\text{Lycopene content} = + 9.841E\text{-}003 - 5.000E\text{-}004\,x\,A - 1.463E\text{-}003\,x\,B - 2.238E\text{-}003\,C + 7.250E - 004\,AB + 6.250E\text{-}004A^2 + 1.050E\text{-}003\,B\,C \quad \text{.....(3)}$$

CONCLUSION

This research has successfully determine the optimum conditions (NaCl concentration, dehydration time and dehydration temperature) suitable for the osmo-dehydration tomato (*Solanum lycopersicum)* in order to determine the amount of lycopene retained in comparison with cabinet drying. The ANOVA showed that effect of the Nacl concentration, dehydration time and dehydration temperature were all significant ($p<0.05$).

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