DEHYDRATION PROCESS OPTIMIZATION FOR MAXIMUM Lycopene RETENTION IN TOMATO SLICES USING RESPONSE SURFACE METHODOLOGY

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ABSTRACT
An investigation was carried out to optimize the time, temperature and slice thickness for dehydration of tomato slices in vacuum oven so that the lycopene losses were minimized. The optimization was done using Box-Behnken method of design expert (R.S.M.), keeping other nutritional factors of tomato slices within range. Optimum conditions for vacuum drying were 2 hrs treatment time at at 80°C temperature and 7 mm slice thickness. The dehydrated product was found with 8.52 mg/100g lycopene which was close to the original value of lycopene found in raw tomatoes.

Key words: Dehydration, Lycopene, Process optimization, R.S.M., Tomato slices, Vacuum oven.

INTRODUCTION

Tomato is highly perishable and its shelf life can be improved by drying to minimize post harvest losses. Tomato is a good source of minerals, sugar, amino acids, vitamin (ascorbic acid) and volatile metabolites (Socaci et al., 2014), dietary fiber (Rajkumar et al., 2006) and lycopene. The color of red tomatoes (Solanum lycopersicum) is mostly from lycopene, which is of interest to consumers and the tomato industry because of its protective effects against diabetes, cardiovascular disorders and various types of cancers (Panthee et al., 2013).

Drying at higher temperatures may cause serious damage to the color, flavor, texture, rehydration ratio and nutrients of the dehydrated product (Prakash et al., 2004 and Praveenkumar et al., 2006). The undesirable quality changes in the dehydrated product are also due to the presence of oxygen in the drying medium-Dehydration of food with antioxidant properties is difficult in the presence of oxygen because of having oxidative heat damage (Zonuni et al., 1999).

Vacuum oven drying has been proposed as a rapid and efficient drying alternative to conventional hot air drying. The advantages of vacuum oven drying technique include faster drying time at lower temperatures and improved product quality (Askari et al., 2009). Response Surface Methodology (RSM) is a collection of mathematical and statistical technique that is useful for modeling and analysis in applications where a response (or output) is influenced by several factors. (Murphy et al., 2003 and Bansal et al., 2013). It is widely used for multivariable optimization studies to determine the optimal values for process parameters.

Limited information is available on vacuum drying of tomatoes. Drying of tomato slices using optimum conditions under vacuum drying might help to produce quality dried products. This study was conducted to determine optimum time, temperature and slice thickness conditions for vacuum assisted drying of tomato slices so that the lycopene losses were minimized.

MATERIALS AND METHODS

Tomato sampling and sample preparation: The fully ripe deep red colored and fresh tomatoes of Hisar Lalima (Sel-18) variety were obtained from the Vegetable Department of CCS HAU, Hisar, India during winter season. Tomatoes were stored in refrigerator at 5°C until drying experiments were completed.

For each test, the required quantities of the samples were taken out of the refrigerator and allowed to warm up to room temperature. Tomatoes were then washed under fresh tap water for 1 min,
superficially dried with the use of filter paper to remove the surface water, and finally sliced into circular discs of various thicknesses as per the box-behnken statistical design of RSM requirements using a hand operated adjustable mechanical slicer.

**Lycopene analysis:** Lycopene content (mg/100gm) in triplicate was determined using spectrophotometric method after extracting lycopene in petroleum ether and analysed at 503nm wavelength, as given by Ranganna (1986). 10 gm of tomato sample was crushed in pestle and mortar with acetone and transferred to a 500 ml separating funnel already containing 15 ml of petroleum ether using Whatman 50 filter paper and mixed gently. The lycopene pigment was transferred into petroleum ether by diluting the acetone (lower phase) with water containing 5% Na₂SO₄ in separating funnel. The funnel was shaken gently in an inverted position for 30 sec. This step removed water from the tomato sample, thus helping to form stable emulsion of lycopene and petroleum ether. Than the lower phase was discarded and top phase of petroleum ether containing the dissolved lycopene pigment transpired to an amber coloured bottle. Repeated extraction of acetone phase was done with ether until it became colourless. About 1-2gm of anhydrous Na₂SO₄ was added to the petroleum ether extract and volume made to 50ml made with petroleum ether in a volumetric flask. 5ml from this aliquot (extract) was further diluted to 50ml with petroleum ether and analysed immediately.

**Experimental design:** The response surface methodology (RSM) was applied using a commercial statistical package, Design-Expert, version 8.0.4 (Statease Inc., Minneapolis, USA), for optimization of three variables of vacuum oven i.e. Time (hrs), Temperature(°C) and Slice thickness (mm) using one major response of lycopene retention. A three-factor and three-level Box-Behnken screening design was used to evaluate linear, interactive, and quadratic effects of the process parameters, to optimize the vacuum oven dehydration process of tomato slices. A constant vacuum of 15psi was maintained in oven during all the experiments. Box-Behnken design consisting of 17 experimental runs including five replicates at centre point was employed. The order of experiments has been fully randomized. The data were analyzed by multiple regressions using the least-squares method. A second order polynomial equation was used to express the responses as a function of the independent variables given as:

\[ Y = \beta_0 + \beta_1 A + \beta_2 B + \beta_3 C + \beta_{11} A^2 + \beta_{22} B^2 + \beta_{33} C^2 + \beta_{12} AB + \beta_{13} AC + \beta_{23} BC \]  

Where, Y was the response variable i.e. lycopene retention (mg/100gm) ; A, B and C represents the independent variables (A = Time of treatment, B = Temperature of the vacuum oven and C = Thickness of tomato slices); \( \beta_n \) were constant regression coefficients (\( \beta_1, \beta_2 \) and \( \beta_3 \) were the linear regression coefficients, \( \beta_{11}, \beta_{22} \) and \( \beta_{33} \) were the quadratic regression coefficients and \( \beta_{12}, \beta_{13} \) and \( \beta_{23} \) were the cross-product regression coefficients). The test of statistical significance was performed on the total error criteria, with a confidence level of 95%. The significant terms in the model were found by analysis of variance (ANOVA) for the response of lycopene retention. By calculating \( R^2 \) and adjusted \( R^2 \), adequacy of the model was checked and response optimization was done by numerical optimization technique of the Design-Expert software.

**RESULTS AND DISCUSSION**

The chemical composition of raw tomato is presented in Table 1. The physicochemical composition of fresh tomato falls within the range, reported for different tomato cultivars by other researchers (Nguyen and Schwartz, 1999, Al-Wandani et al., 1985).

Various responses of lycopene are listed in Table 2. The experimental data was used to calculate the coefficients of the quadratic equation, and Table 3 summarizes the significant coefficients of the second order polynomial equation. For any of the terms in the model, a large regression co-efficient

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture (%)</td>
<td>92.63±0.84</td>
</tr>
<tr>
<td>TSS (°Brix)</td>
<td>6.13±0.29</td>
</tr>
<tr>
<td>Titratable acidity (% anhydrous citric acid)</td>
<td>0.59±0.03</td>
</tr>
<tr>
<td>Ascorbic acid (mg/100g)</td>
<td>18.44±0.79</td>
</tr>
<tr>
<td>Lycopene (mg/100g)</td>
<td>11.82±0.89</td>
</tr>
</tbody>
</table>

Values are means (±SD) of triplicate determinations.
and a small p-value would indicate a more significant effect on the respective response variables. ANOVA showed that the resulting quadratic model adequately represented the experimental data, with coefficients of multiple determinations (R^2) of 0.95 for the response of lycopene. The model used in this study was able to identify the optimum operating conditions for vacuum oven drying of tomato slices.

**Influence of variables on lycopene:** The maximum lycopene content (9.42 mg/100g) at coded point (-1, -1, 0) was about 1.25 times more than the minimum lycopene content (7.51 mg/100g) at the coded point of (1, 1, 0) with an average value of 8.23 mg/100g sample (Table 2). The lycopene content varied between 8.52 - 9.42 mg/100g at 2 hrs drying time and its quantity ranged between 7.51 - 8.05 mg/100g when the drying time increased to 7 hr. The coefficients of the model are given in Table 3. The Model F value of 16.09 implies that model was significant (P < 0.05). R^2 and Adjusted R^2 values of the model were 0.9539 and 0.8946, respectively. The adequate precision value of 14.563 indicates that the model can be used to navigate the design space as it is greater than 4.0 (Montgomery, 2001). Considering these criteria, following response model was selected for representing the variation of lycopene content for further analysis.

\[
Y = 8.22 - 0.61A - 0.39B + 0.053C + 0.26A^2 - 0.11B^2 - 0.13C^2 + 0.092AB + 0.027AC + 0.0025BC \break (2)
\]

Where: A, B and C are the coded values of time (hrs), temperature (°C), and thickness (mm), respectively.

Analysis of variance of Equation 1 (Table 3) showed that F-values for linear term of time and temperature were 92.54 and 38.14, respectively and p value < 0.0001, showing that the A and B were significant terms. It is evident from Equation 2 that coefficient of A and B were negative, but that of C was positive. Therefore, increase in time and temperature may reduce the lycopene, whereas...
increase in slice thickness may increase the lycopene content of the product quantitatively. The coefficients of $A^2$ was positive therefore they show positive quadratic effect on moisture content while $B^2$ and $C^2$ were negative therefore they show negative quadratic effect on lycopene content. The interactive effect of all the process conditions on lycopene content of vacuum oven dried tomato slices is shown in Figs. 1, 2 and 3.

The heating has a pronounced effect on lycopene content as high temperature causes its decrease because of isomerization and oxidation. The increased losses of lycopene were also reported when the holding times at high temperature are long (Shi & Le Maguer, 2000) which also supports the present study. The slice thickness had not found any significant effect on lycopene content that can be shown in Figs 2 and 3.

Optimization: Second-order polynomial model was utilized for response to determine the specified optimum drying conditions. The optimization was applied for selected ranges of time, temperature, and slice thickness as 2-7 hr, 50-80°C, and 5-9 mm, respectively. By applying desirability function method, the solution was obtained with desirability value of 0.657. The solutions were obtained for the optimum vacuum drying as 80°C for temperature, 2 hr for time, and 7 mm for slice thickness. At this point, lycopene content was predicted as 8.49mg/100g sample, while experimental value was 8.52 mg/100g. Interestingly, small deviation was found between the experimental and predicted value. Therefore, the models obtained in this study could be used to optimize the vacuum oven drying of tomato slices.

CONCLUSION

A simple vacuum oven drying technology was able to retain lycopene at its maximum level. Response surface methodology successfully determined the optimum conditions for vacuum drying of tomato slices. The drying process
parameters i.e. time, temperature, and slice thickness had significant effect on lycopene content. The predicted and experimental values were not significantly different that is why the model showed its ability to optimize the drying process.

REFERENCES