Influences of Osmotic Dehydration on Drying Behavior and Product Quality of Coconut (Cocos nucifera)

Animesh Sarkar1*, Tushar Ahmed1, Mahabub Alam1, Somrita Rahman1 and Shishir Kanti Pramanik2

1Department of Food Engineering and Tea Technology, Shahjalal University of Science and Technology, Sylhet 3114, Bangladesh.
2Department of Chemistry, Shahjalal University of Science and Technology, Sylhet 3114, Bangladesh.

Authors’ contributions

This work was carried out in collaboration among all authors. Author AS designed and supervised the study. Authors TA and SR performed the analysis. Authors MA and AS wrote the first draft of the manuscript. Authors MA and TA analyzed the data. All the authors managed the literature search and wrote the final manuscript. All authors read, edited and approved the final manuscript.

Article Information

DOI: 10.9734/AFSJ/2020/v15i330153
Editor(s): Dr. Vijaya Khader, Acharya N. G. Ranga Agricultural University, India.
Reviewers:
(1) Krzysztof Gómicz, Warsaw University of Life Sciences, Poland.
(2) Konan N’Guessan Ysidor, Peleforo Gon Coulibaly University, Côte d’Ivoire.
Complete Peer review History: http://www.sdiarticle4.com/review-history/56862

Received 01 March 2020
Accepted 06 May 2020
Published 14 May 2020

ABSTRACT

This research was conducted to assess the drying kinetics and product quality during osmotic dehydration and air drying of coconut cuts. The coconuts were osmotically pretreated by different concentration of sugar solution (40 °Brix, 50 °Brix, and 60 °Brix) and temperature of osmotic solution (35°C, 45°C and 55°C) were maintained. The proportion of fruit to solution was maintained 1:4 (w/v) and pretreatment process length was 3 hours. Higher osmotic solution temperature at 55°C with low concentration 40 °Brix resulted in a huge reduction of antioxidant activity, vitamin C, polyphenol, and color contents while higher osmotic solution concentration at 50 °Brix with lower temperature 35°C held more. The present investigation likewise exhibited that moisture loss and solute gain rate extended with the increasing of osmotic solution temperature and concentration. The outcomes demonstrated that drying regime was typically in the falling rate period. We used regression analysis to the experimental drying data to fit three thin layer drying models. The most

*Corresponding author: Email: animeshsarkarbau@gmail.com, animesh-fet@sust.edu;
appropriate model(s) was selected using correlation coefficient (R²) and root mean square error (RMSE). The page model showed a better fit of the experimental drying data (as compared to other models) on the basis that R² > 0.9997 and RMSE < 0.0011. These data represent a good contribution to further investigation on the mass transfer kinetics and also demonstrated that fruits could be preserved with higher nutrient applying osmotic dehydration technique.

Keywords: Osmotic dehydration; coconut; drying kinetics; bioactive compounds.

1. INTRODUCTION

Coconut (Cocos nucifera) is found along sandy shorelines throughout the tropics. In tropical low land, it is developed for business purposes and normally found in warmer subtropical regions [1]. Coconut is one of the most important nut crops in Bangladesh where its production was 374269 Metric tons in 2015-16 against 408635 Metric tons in 2016-17 [2]. Due to the absence of sufficient postharvest and preservation method, numerous bunches of fruits are lost each year. That's why, there is increased attention to minimize these losses by processing of these fruits and include those processed fruits in value added products [3]. There are several techniques to minimize the losses and develop diversified products which are already practiced over the world. Among them, drying is a unique method for processing and long-term storage of fruits and vegetables in dried form. But the quality deterioration, namely, discoloration, case hardening, and shrinkage of food due to drying is significant and high drying temperature can lead a complete loss of phenolic components in several fruits [4]. According to Rekha et al. [5] 30–40% ascorbic acid can be lost in some fruits by the dehydration. To retain the functional compounds and enhance the quality of product, several pretreatments could be implemented before drying [6]. Among different pretreatment strategies such as chemical treatment, gas treatments, thermal blanching (hot water, steam, super-heated steam impingement, ohmic and microwave heating), and non-thermal process (ultrasound, freezing, pulsed electric field, and high hydrostatic pressure), osmotic dehydration is usually applied to food dewatering which prompts alluring items by retaining beneficial nutrients [7]. Few researches have just been done to assess the impact of osmotic dehydration on moisture loss, solid gain and characterization of physicochemical properties of coconut and other fruits [8-10]. As per our best knowledge, no attempts have been made to use osmotic dehydration and constant drying treatments for coconut preservation in Bangladesh. However, the current research exhibited the interest in evaluating the impact of different concentration of an osmotic solution with various temperature on the physicochemical, antioxidant properties and mass transfer kinetics of the new variety of coconut. The research additionally designed to apply several scientific models to assess the mass transfer kinetics during osmotic dehydration and to evaluate the effects of osmotic dehydration on physicochemical and antioxidant properties of hot air-dried coconut.

2. MATERIALS AND METHODS

2.1 Sample Collection

Matured coconuts were procured from the local market in Sylhet, Bangladesh. Coconut average weight of 1.2 to 1.4 kg were chosen for the study. The commercial sugar was considered as osmotic agent being cheap and easily available.

2.2 Sample Preparation

Coconut was first husked. The shell was broken by a hammer. Using a stainless-steel cutter the endosperm was cut into dimension of 6.0×3.0×0.5 cm [11]. Sugar Syrups of different concentration (40 °Brix, 50 °Brix, and 60 °Brix) were prepared by dissolving exact quantity of sugar in water.

2.3 Osmotic Dehydration

The prepared coconut slices were immersed into different concentration of syrup solution of 40, 50, and 60 °Brix at different syrup temperature of 35, 45, and 55°C for osmotic dehydration. Fruit to solution ratio was 1:4 (w/v) during osmotic dehydration. The samples were kept for three hours. Pieces were separated from the solution after 3 hours and sprayed with water to displace the solute within fruit surface. Surface water was removed by adsorbent paper before drying.
2.4 Convective Drying and Storage

After pretreatment, the samples were placed in a dryer tray. Drying operation was carried out in a constant temperature and humidity chamber (Model: VS-811H-150 input 230 V-50Hz 16 A 1 phase) at 60°C temperature and 60% relative humidity. The weight changes were recorded by 60 mins interval for determining the drying behavior of coconut. Lastly, the samples were kept in a zip locked airtight polyethylene film bags and stored at -20°C until further analysis.

2.5 Determination of Moisture Content

Moisture content of coconut was determined by the method of Helvich [12] in which a sample was dried at some elevated temperature and reported the loss in weight in terms of moisture.

2.6 Mathematical Modelling of Drying Data

The moisture content data obtained from the drying experiment was converted into moisture ratio (MR) and then fitted to the Three models such as Lewis (Newton): MR=exp(-kt), Handerson and Pabis: MR=aexp(-kt) and Page models: MR=(-kt^n) respectively. The MR of the samples is calculated by the following equation.

\[ MR = \frac{M_t - M_e}{M_o - M_e} \]  
(1)

where, Mt represents the moisture content at a particular time (g water/g dry matter), Mo corresponds to the initial moisture content (g water/g dry matter), Me corresponds to the equilibrium moisture content (g water/g dry matter) [11]. MR = moisture ratio, k= drying rate constant, a, n= empirical constants, t= drying time.

2.7 Fitting of Mathematical Model

Modeling of drying kinetics of food samples is important for drying process and used to determine moisture content of samples at any drying time. MR is obtained by using equation. In order to select mathematical equation that describes the moisture content and time data, we need the correlation coefficient \( R^2 \), the reduced chi-square \( (x^2) \) and root mean square of error (RMSE).

\[ R^2 = \frac{\sum_{i=1}^{N}(MR_{\text{exp},i} - MR_{\text{exp,mean},i})^2 - (MR_{\text{pre},i} - MR_{\text{exp},i})^2}{\sum_{i=1}^{N}(MR_{\text{exp,mean},i})^2} \]  
(2)

where, \( R^2 \) is the correlation coefficient, MR_{exp,i} stands for the experimental moisture ratio found in any measurement, MR_{pre,i} is the predicted moisture ratio for the measurement and \( N \) is the total number of observations [13].

\[ RMSE = \sqrt{\frac{\sum_{i=1}^{N}(MR_{\text{ip}}-MR_{\text{ie}})^2}{N}} \]  
(3)

where, MR_{ip} is the predicted dimensionless moisture ratio, MR_{ie} is the experimental dimensionless moisture ratio, \( N \) is the number of observations and \( n \) is the number of constants in the mathematical equations. The higher values of \( R^2 \), lower values of RMSE indicate better fitness of drying curves according to the moisture and time data.

2.8 Phytochemical Analysis

2.8.1 Test for flavonoids

Two ml of the sample were added with 2 ml of 10% NaOH in a test tube. A yellow color was formed. The yellow color turned colorless after addition of 2 ml of diluted HCl which confirmed the presence of Flavonoids [14].

2.8.2 Test for alkaloids

Two ml of the sample was added with 2 ml of 10% HCl. 1 ml of picric acid solution was mixed to the acidic medium. Alkaloids was confirmed by yellow precipitation [14].

2.8.3 Test for steroids

Firstly, 2 ml of the sample were mixed with 10 ml of chloroform. After that 10 ml of conc. sulphuric acid was cautiously added by the side of the test tube. The presence of steroid was assured by the red upper layer whereas the sulphuric acid layer turned yellow with green fluorescence [15].

2.8.4 Test for glycoside

Two ml of the sample were added with 2 ml of acetic acid. In a cold water bath, the mixture was cooled. After that, 2 ml of concentrated sulphuric acid added. The color change from blue to bluish green confirmed the presence of glycoside [16].

2.8.5 Test for terpenoids

Two ml of the sample were added carefully with 2 ml of chloroform and 1 ml of concentrated sulphuric acid that formed a layer. Clear upper and lower layers with a reddish brown interphase indicated the positive result [15].
2.9 Determination of Antioxidant Properties of Air-Dried Coconut

2.9.1 Determination of 2, 2-diphenyl-1-picrylhydrazyl (DPPH) activity

DPPH activity was estimated by the method of Saikia et al. [17]. Radical scavenging activity of the sample extracts was measured by determining the inhibition rate of DPPH (2,2-diphenyl-1-picrylhydrazyl) radical. 39.1 mg DPPH were mixed in 1000 ml methanol to prepare DPPH radical methanolic solution (0.1 mM). After that 80 ml methanol was taken in volumetric flask and distilled water was added up to 100 ml. The solution was then stored in darkness for 48 hours. Extracts in 200 μl were added to 2.8 ml DPPH radical methanolic solution. After 30 seconds in vortex machine (M.N. VM-2000, Taiwan), solutions were placed in a dark place for 30 minutes. The absorbance was measured at 517 nm using a UV-Vis Spectrophotometer (UV-Vis PG Instruments limited, Model-T60 U). The results were calculated in terms of radical scavenging activity using the following equation.

\[
\text{Radical scavenging activity (\%)} = \frac{A_o - A_s}{A_o} \times 100\% \tag{4}
\]

where, \(A_o\) is absorbance of control blank, and \(A_s\) is absorbance of sample extract.

2.9.2 Determination of total phenolic content

The samples were extracted in accordance with the method of SaikiaMahnot [17] by using 80% acetone. The solutions were incubated in a shaking incubator at 20°C for 90 minutes. After the incubation period, the crude extract was centrifuged (Gyrozen-Benchtop centrifuge, Model-416G, Korea) at 3,000 rpm for 15 minutes. The extracts were then kept at -20°C until further analysis. The Total Phenolic content was estimated with the Folin-Ciocalteu assay by the method of Slinkard and Singleton [18] by using 20 μl of extract, gallic acid standard or blank, 1.58 ml of distilled water, 100 μl of Folin-Ciocalteu reagent are added properly and 300 μl of sodium carbonate was mixed within 8 min. The samples were vortexed well and kept in the dark place for 30 min at 40°C. Blank was prepared with water instead of coconut sample and absorbance was measured at 765 nm in a UV-Vis spectrophotometer. The results were expressed in mg gallic acid equivalent (GAE)/100g. A set of standard solution was read against blank.

2.9.3 Determination of ascorbic acid

The Ascorbic Acid was estimated by the described method of Ranganna [19] according to the reduction of 2,6-dichlorophenol indophenols by ascorbic acid.

2.10 Measurement of Color Change

The color measurement was performed by the method of XIAO et al. [20]. A colorimeter was utilized to measure the color of fresh and dried coconut (PCE-CSM 4). The color was categorized as L-values for lightness, a-values for redness/greenness and b-values for yellowness/blueness. \(L_0^*\), \(a_0^*\) and \(b_0^*\) are the color parameters of fresh samples. Prior to each measurement, the colorimeter was calibrated on a standard white and black plate. A glass cell containing a sample was placed close to the nose cone of the colorimeter and above the light source to register \(L_0^*\), \(a_0^*\), \(b_0^*\), \(L^*\), \(a^*\) and \(b^*\) values. Measured were read on the surface of the sample. The mean value of three readings was determined randomly on the sample. Additionally, the chroma C, hue angle \(\alpha\) and total color differences \(\Delta E\) were calculated and these were used to describe the change in color.

\[
C = \sqrt{(a^2 + b^2)} \tag{5}
\]

\[
\alpha = \tan^{-1} \frac{b}{a} \tag{6}
\]

\[
\Delta E = \sqrt{(L^* - L_0^*)^2 + (a^* - a_0^*)^2 + (b^* - b_0^*)^2} \tag{7}
\]

where, \(L\)-values for lightness, \(a\)-values for redness/greenness and \(b\)-values for yellowness/blueness. \(C\), \(\alpha\) and \(\Delta E\) are the chroma, hue angle and total color differences.

2.11 Statistical Analysis

Measurements were carried out in triplicates and data obtained from experiments were gathered and analyzed using the SPSS software. Data were expressed as mean ± SD. One-way analysis of variance (ANOVA) were used to test the statistical difference. Differences with p-values among the treatments < 0.05 were considered statistically significant.

3. RESULTS AND DISCUSSION

3.1 Physicochemical Properties of Osmotically Pretreated Air-dried Coconut

The average moisture content of fresh coconut was 52.28%. After osmotic pretreatments,
moisture contents were decreased (Table 1). This Phenomena can be explained as the effect of osmotic pressure on mass transfer, resulting in the removal of water from the tissue of coconut and replaced by soluble solids [21]. The average moisture content at 40 °Brix, 50 °Brix, and 60 °Brix were 45.96, 40.89, and 39.64% respectively. The results were similar to UdomkunNagle [7] for air drying of osmotically pretreated coconut. The available water in a food exhibits microbial growth and takes part in chemical reactions and spoilage processes. Water activity is more important for food stability, chemical and microbial, than total water content. Water activity decreases with the decrease in moisture content. Spoilage microorganisms can't survive at lower water activity level. The present research had showed the lower moisture content values for 60 °Brix osmotic solutions. This might be because of the high concentration of osmotic solution resulting in the removal of more water from the tissue of coconut. This is in line with Tsironi and Taoukis [22].

### 3.2 Drying Models Prediction

The most appropriate model(s) capable of predicting the drying data of pre-osmosised coconut samples was selected on the basis of the highest $R^2$ and lowest RMSE values. The page model had a good fitting of data in terms of $R^2 > 0.999$ and RMSE < 0.0013 for all the tested coconut samples [13].

Therefore, the page model is proposed as the best model describing the drying behavior of non-osmosised and osmosised coconut samples dried at 60°C [23] (Table 2).

### 3.3 Phytochemical Analysis

Alkaloid displayed moderate concentration in coconut slices. The presence of alkaloid was shown in study of Odenigbo and Otisi [24] in coconut seed flesh which supports the present study. Alkaloid which is a bioactive constituent of plants is responsible for its medical value of the respective plant food [25].

Steroid was present in the coconut slices. Steroid is given to the mother or feeding mothers to ensure their hormonal balance because the steroidal structure could serve as potent starting material in synthesis of these hormones [26].

<table>
<thead>
<tr>
<th>Pretreatments</th>
<th>Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concentration of osmotic solution(°Brix)</td>
<td>Temperature(°C)</td>
</tr>
<tr>
<td>35</td>
<td>49.09±0.36°</td>
</tr>
<tr>
<td>40</td>
<td>46.35±0.23°</td>
</tr>
<tr>
<td>45</td>
<td>42.46±0.56°</td>
</tr>
<tr>
<td>50</td>
<td>42.23±0.09°</td>
</tr>
<tr>
<td>55</td>
<td>41.18±0.04°</td>
</tr>
<tr>
<td>50</td>
<td>39.28±0.03°</td>
</tr>
<tr>
<td>60</td>
<td>39.37±0.78°</td>
</tr>
<tr>
<td>55</td>
<td>38.47±0.23°</td>
</tr>
</tbody>
</table>

The values are expressed as mean ± SD of three independent determinations. Values with the same superscripts within each concentration group indicate no significant difference (P≤0.05)

### Table 1. Physicochemical properties of osmotically dehydrated coconut

<table>
<thead>
<tr>
<th>Temp. (°C)</th>
<th>Conc. (°Brix)</th>
<th>Lewis (Newtonian) model</th>
<th>Handerson and Pabis model</th>
<th>Page model</th>
<th>Lewis (Newtonian) model</th>
<th>Handerson and Pabis model</th>
<th>Page model</th>
</tr>
</thead>
<tbody>
<tr>
<td>35</td>
<td>40</td>
<td>0.9997</td>
<td>0.9949</td>
<td>0.9991</td>
<td>0.0001</td>
<td>0.0006</td>
<td>0.023</td>
</tr>
<tr>
<td>50</td>
<td>0.9949</td>
<td>0.9932</td>
<td>0.9989</td>
<td>0.0006</td>
<td>0.0004</td>
<td>0.0009</td>
<td></td>
</tr>
<tr>
<td>60</td>
<td>0.97271</td>
<td>0.9523</td>
<td>0.9999</td>
<td>0.0023</td>
<td>0.0017</td>
<td>0.0015</td>
<td></td>
</tr>
<tr>
<td>45</td>
<td>0.9979</td>
<td>0.9973</td>
<td>0.9994</td>
<td>0.0005</td>
<td>0.0008</td>
<td>0.0008</td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>0.9661</td>
<td>0.9367</td>
<td>0.9977</td>
<td>0.0019</td>
<td>0.0011</td>
<td>0.0017</td>
<td></td>
</tr>
<tr>
<td>60</td>
<td>0.9962</td>
<td>0.9919</td>
<td>0.9974</td>
<td>0.0018</td>
<td>0.0012</td>
<td>0.0014</td>
<td></td>
</tr>
<tr>
<td>55</td>
<td>0.9761</td>
<td>0.9999</td>
<td>0.9999</td>
<td>0.0030</td>
<td>0.0021</td>
<td>0.0006</td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>0.9989</td>
<td>0.9812</td>
<td>0.9999</td>
<td>0.0038</td>
<td>0.510</td>
<td>0.014</td>
<td></td>
</tr>
<tr>
<td>60</td>
<td>0.9724</td>
<td>0.9756</td>
<td>0.9997</td>
<td>0.0038</td>
<td>0.510</td>
<td>0.014</td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Determination of $R^2$ and RMSE values for coconut samples
3.4 Total phenolic content (TPC)

After osmotic pretreatment, total phenolic content (TPC) of coconut decreased. In the fresh coconut, TPC was about 6.35±0.02 mg GAE/100 g d.w. whereas the osmotically pretreated hot air-dried coconut contained TPC ranging between 2.38±0.05 and 4.86±0.02 mg GAE/100 g d.w. The reduction of total phenolic compounds after the OD process and drying was due to the migration of phenolic compounds from coconut to osmotic solution induced by osmotic driving force [31]. After the osmotic dehydration and drying, the total phenolic content of the treated samples was greatly decreased than the fresh ones (at p ≤ 0.05) (Table 4). The TPC content (4.86±0.02 mg GAE/100 g d.w.) was found more in the samples treated with 60 °Brix and 35°C OD process. This might be due to the higher concentration of the osmotic solution effectively coated by the samples during OD process. Moreover, the TPC content (2.38±0.05 mg GAE/100 g d.w.) was found less in the dried coconut sample treated with lower concentration of osmotic solution and higher temperature of the OD process. These results comply with the findings of Osae et al. [32].

3.4.2 Ascorbic acid

The osmotically pretreated hot air-dried coconut samples were analyzed for their antioxidant properties. The ascorbic acid was found 3.3±0.1 (mg/100 g d.w.) in a fresh sample which is significantly different to the dried samples (at p ≤ 0.05). The osmotic pretreatment could have played a significant role on the retentions of the heat sensitive ascorbic acid. The coconut samples treated with a higher concentration of the osmotic solution and lower temperature showed a greater amount of ascorbic acid after drying. The findings of the current study complied with the study conducted by Garcia et al. [33] and El-Ishaq and Obirinakem [34]. Ascorbic acid of the treated samples ranged from 1.56 to 2.85 mg/100 g d.w. The lowest quantity of ascorbic acid was found at 40 °Brix and 55°C and the quantity was almost 17.44 mg/100 g d.w. Ascorbic acid losses were significantly higher in the samples treated with lowest concentration of the osmotic solution. The conceivable explanation is that the lower concentration of the osmotic solution might not appropriately coat the sample so that more loss of ascorbic acid occurred during drying (Table 4).

3.4.3 Antioxidant activity (DPPH Assay %)

The effects of antioxidants on DPPH radical scavenging show due to their hydrogen giving capacity. The higher antioxidant scavenging activity, the higher reduction of the DPPH assay [35]. The antioxidant activity as DPPH of the fresh sample was 70.44±0.02% whereas the osmotically pretreated dried samples exhibited values ranged from 45.39±1.86 to 58.78±0.58% (Table 4). The antioxidant activity of the dried samples was greatly decreased during osmotic dehydration and the drying process (p ≤ 0.05). Some endogenous antioxidants might be destroyed due to the higher temperatures [7].
3.5 Color Changes

Consumers first evaluate the color of the food surface as the first quality parameter even before they taste it, so that color is a critical indicator in product acceptance. L∗, a∗ and b∗ values of fresh coconut slices were 91.23±0.03, -0.26±0.05 and 3.39±0.007 respectively. The drying treatments significantly influenced the color parameters of the samples. The decrease of L∗ value in all drying methods led to dried slices having a dark color as compared with fresh samples. Negative a∗ value which indicates greenness was seen in fresh samples. After drying, positive a∗ values which indicate red hues were observed. A significant increase in the b∗ values was recorded in all dried coconut samples. Positive b indicates yellowness while negative b indicates blue. Drying particularly influenced the Hunter L∗, a∗ and b∗ parameters. When looking at the fresh sample, dried samples had higher C values and closely followed the b∗ values. ΔE is a function of the L0∗, a0∗, b0, L∗, a∗ and b∗ values, the ΔE values were also analyzed. The ΔE values of dried samples increased in relation to the increase in drying temperature. This also can be linked to the effect of high temperature on heat-sensitive components, such as proteins and carbohydrates. Between proteins and amino acids, there is an occurrence of a very common non-enzymatic browning reaction in food products. This occurrence that reduces sugars during heating is the Maillard reaction which produces dark pigment and destroys the natural color of the products [36]. Apart from the Maillard reaction, color changes resulting from the thermal treatment may also be caused by decomposition of chlorophyll and carotenoid [11,37,38].

4. CONCLUSION

In this study, osmotic dehydration was applied as pretreatment prior to drying to allow the retention of functional properties of coconut and mass...
transfer kinetics of coconut. Functional properties such as vitamin C, Antioxidant activity, polyphenol, and color were decreased with increase in pretreatment temperature. However, with higher concentration of osmotic solution and lower pretreatment temperature it was seen higher retention of functional properties respectively with higher pretreatment temperature. 50 °Brix syrup solution with 35°C syrup solution temperature shown higher retention quality for beneficial nutrition of coconut.

Osmotic dehydration reduces considerably the drying rate and drying time of coconut samples due to loss of the initial water content. The osmotic dehydration is a precondition which had a significant influence on the thermal air-drying behavior of coconut. The proposed thin layer drying model of page provides an adequate preliminary description stage for the drying behavior of coconut and this could represent a significant tool for engineering purposes.

It can be concluded that osmotic dehydration is an alternative process to increase the quality of coconut which can be used in dairy products, cakes, breads, pasta etc to increase their nutritive and flavor qualities.

ACKNOWLEDGEMENTS

The authors are thankful to the Department of Food Engineering and Tea Technology, Shahjalal University of Science and Technology for continuous material support and technical assistance.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

17. Saikia S, Mahnot NK, Mahanta CL. Optimisation of phenolic extraction from Averrhoa carambola pomace by response surface methodology and its micro-encapsulation by spray and freeze drying. Food Chemistry. 2015;171:144-152.
36. Nguyen ML, Schwartz SJ. Lycopene: Chemical and biological properties: Developing nutraceuticals for the new


© 2020 Sarkar et al.; This is an Open Access article distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/56862