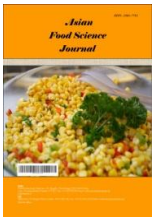

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Influences of Osmotic Dehydration on Drying Behavior and Product Quality of Coconut (*Cocos nucifera*)

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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.

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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

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appropriate model(s) was selected using correlation coefficient (R^2) 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 R^2> 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 characterizations 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.

$$MR = \frac{Mt-Me}{Mo-Me} \quad (1)$$

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).

$$R^2 = \frac{\sum_{i=1}^{N}(MRexp,i - MRexp,mean,i)^2 - (MRpre,i - MRexp,i)^2}{\sum_{i=1}^{N}(MRexp,i - MRexp,mean,j)^2} \quad (2)$$

where, R^2 is the correlation coefficient, MRexp,i stands for the experimental moisture ratio found in any measurement, MRpre,i is the predicted moisture ratio for the measurement and N is the total number of observations [13].

$$RMSE = \sqrt{\frac{\sum_{i=1}^{N}(MRip-MRie)^2}{N}} \quad (3)$$

where, MRip is the predicted dimensionless moisture ratio, MRie 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-l-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.

$$\text{Radical scavenging activity } (\%) = \frac{\text{Ao}-\text{As}}{\text{Ao}} \times 100\% \quad (4)$$

where, Ao is absorbance of control blank, and As 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 α and total color differences ΔE were calculated and these were used to describe the change in color.

$$\text{C} = \sqrt{(a^2 + b^2)} \quad (5)$$

$$\alpha = \tan^{-1} b/a \quad (6)$$

$$\Delta\text{E} = \sqrt{(L^* - L_0)^2 + (a^* - a_0)^2 + (b^* - b_0)^2} \quad (7)$$

where, L-values for lightness, a-values for redness/greenness and b-values for yellowness/blueness. C, α and ΔE 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 ºBrix, 50 ºBrix, and 60 ºBrix 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 ºBrix 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 1. Physicochemical properties of osmotically dehydrated coconut

Pretreatments		Parameters
Concentration of osmotic solution(°Brix)	**Temperature(°C)**	**Moisture Content (%)**
40	35	49.09±0.36[a]
	45	46.35±0.23[b]
	55	42.46±0.56[c]
50	35	42.23±0.09[a]
	45	41.18±0.04[ab]
	55	39.28±0.03[b]
60	35	41.09±0.04[a]
	45	39.37±0.78[ab]
	55	38.47±0.23[b]

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 2. Determination of R^2 and RMSE values for coconut samples

Temp. (°C)	Conc. (°Brix)	R^2			RMSE		
		Lewis (Newtonian) model	Handerson and Pabis model	Page model	Lewis (Newtonian) model	Handerson and Pabis model	Page model
35	40	0.9997	0.9949	0.9991	0.0001	0.0006	0.0023
	50	0.9949	0.9932	0.9989	0.0006	0.0004	0.0009
	60	0.97216	0.9523	0.9999	0.0023	0.0017	0.0015
45	40	0.9979	0.9973	0.9994	0.0005	0.0008	0.0008
	50	0.9661	0.9367	0.9997	0.0019	0.0011	0.0017
	60	0.9962	0.9919	0.9974	0.0018	0.0012	0.0014
55	40	0.9761	0.9999	0.9998	0.0001	0.0726	0.0001
	50	0.9989	0.9812	0.9999	0.0030	0.0021	0.0006
	60	0.9724	0.9756	0.9997	0.0038	0.510	0.0014

Glycoside was present at moderate concentration in dried coconut slices which supported the study of Obidoa et al. [27]. In the form of inactive glycoside, many plants store chemicals. Enzyme hydrolysis is liable to its activation that causes the breakdown of sugar by producing the chemical available for use. Toxic substances are bound to sugar molecules as a component of their disposal from the body of animal including human [28].

Terpenoids were present in dried coconut slices which supported the study of Odenigbo and Otisi [24]. The antioxidant properties in coconut dried slices confirmed by the presence of terpenoids. Antioxidant reduces the formation of free radicals. They respond with and neutralize the free radicals by which they shield the cell from oxidative injury [29]. Coconut is used to fight arteriosclerosis and retards the growth of cancer cell that is assured by the presence of phenolic content [30].

Flavonoid was absent in dried coconut slices which support the study of Odenigbo and Otisi [24] for Nigerian seed flesh (Table 3).

Table 3. Phytochemical analysis of coconut slices

Phytochemicals	Result
Alkaloid	++
Steroid	+++
Glycoside	++
Terpenoids	+++
Flavonoid	ND

where, + = slightly present; ++ = averagely present; +++ largely present; and ND = not found

3.4 Effect of Osmotic Dehydration on the Bioactive Compounds of Dried Coconut

3.4.1 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 $p \leq 0.05$) (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 $p \leq 0.05$). 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 ($p \leq 0.05$). Some endogenous antioxidants might be destroyed due to the higher temperatures [7].

Table 4. Antioxidant properties of osmotically pretreated hot-air dried coconut

Osmotic Solution Concentration (°Brix)	Osmotic solution temperature (°C)	Total phenolic content (mg GAE/100 g d.w.)	Ascorbic acid (mg/100 g d.w.)	2, 2-diphenyl-1-picrylhydrazyl (DPPH) activity (%)
Fresh	-	6.35±0.02	3.30±0.10	70.44±0.02
	35	3.13±0.01^{a}	2.59±0.04^{a}	49.57±0.27^{b}
40	45	2.69±0.20^{b}	2.07±0.03^{b}	51.88±0.58^{b}
	55	2.38±0.05^{c}	1.56±0.12^{c}	55.29±0.22^{a}
	35	3.95±0.03^{a}	2.75±0.02^{a}	52.32±0.28^{b}
50	45	3.20±0.04^{b}	2.23±0.10^{b}	58.20±0.94^{a}
	55	2.46±0.03^{c}	1.78±0.01^{c}	58.78±0.58^{a}
	35	4.86±0.02^{a}	2.85±0.07^{a}	45.39±1.86^{b}
60	45	3.70±0.12^{b}	2.35±0.04^{b}	47.53±1.17^{b}
	55	3.16±0.01^{c}	1.93±0.07^{c}	52.90±1.33^{a}

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 5. Color values of fresh and dried coconut slices

		Color parameter					
Temp.(°C)	**°Brix**	**L**	**a**	**b**	**C**	**α**	**∆E**
Fresh	-	91.23±0.03	-0.26±0.05	3.39±0.007	3.51±0.02	85.61±0.07	-
	40	80.04±0.87^{a}	1.23±0.02^{a}	6.08±0.01^{a}	6.20±0.01^{a}	78.56±0.04^{a}	11.60±0.05^{b}
35	50	79.56±0.07^{a}	1.04±0.03^{b}	4.62±0.03^{c}	4.74±0.08^{c}	77.31±0.01^{a}	11.80±0.01^{b}
	60	74.09±0.08^{b}	1.18±0.04^{a}	5.68±0.07^{b}	5.80±0.08^{b}	78.26±0.09^{a}	17.35±0.08^{a}
	40	79.31±0.03^{a}	1.48±0.05^{b}	7.46±0.03^{b}	7.61±0.07^{b}	78.77±0.01^{a}	12.71±0.08^{b}
45	50	75.02±0.04^{b}	1.61±0.03^{a}	8.52±0.06^{a}	8.67±0.08^{a}	79.29±0.04^{a}	17.02±0.07^{a}
	60	80.51±0.05^{a}	1.52±0.09^{b}	7.68±0.09^{b}	7.63±0.06^{b}	78.80±0.05^{a}	11.68±0.06^{c}
	40	77.28±0.09^{a}	1.41±0.06^{b}	5.27±0.01^{c}	5.46±0.01^{c}	76.02±0.08^{a}	14.17±0.04^{c}
55	50	75.29±0.04^{a}	1.53±0.10^{a}	8.08±0.05^{a}	8.23±0.08^{a}	79.27±0.02^{a}	16.71±0.02^{b}
	60	69.16±0.01^{b}	1.30±0.01^{c}	5.86±0.04^{b}	6.01±0.07^{b}	77.49±0.01^{a}	22.26±0.01^{a}

The values are expressed as mean ± SD of three independent determinations. Values with the same superscripts within each temperature group indicate no significant difference (P≤0.05). where, L-values for lightness, a-values for redness/greenness and b-values for yellowness/blueness. C, α and ΔE are the chroma, hue angle and total color differences

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_0*, a_0* and b_0^* 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_0* 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. Δ E 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.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Osawa CC, Gonçalves LAG, Ragazzi S. Correlation between free fatty acids of vegetable oils evaluated by rapid tests and by the official method. Journal of Food Composition and Analysis. 2007;20(6): 523-528.
2. BBS. Statistical Year Book of Bangladesh. Bangladesh Bureau of Statistics. Government of the Peoples' Republic of Bangladesh. Dhaka. Bangladesh; 2001.
3. Alam M, Hossain MA, Sarkar A. Effect of edible coating on functional properties and nutritional compounds retention of air dried green banana (*Musa sapientum* L.). IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT). 2020;14(2):51-58.
4. Mrad ND, Boudhrioua N, Kechaou N, Courtois F, Bonazzi C. Influence of air drying temperature on kinetics, physicochemical properties, total phenolic content and ascorbic acid of pears. Food and Bioproducts Processing. 2012;90(3): 433-441.
5. Rekha C, Poornima G, Manasa M, Abhipsa V, Devi JP, Kumar HTV, Kekuda TRP. Ascorbic acid, total phenol content and antioxidant activity of fresh juices of four ripe and unripe citrus fruits. Chemical Science Transactions. 2012;1(2):303-310.
6. Gallo JQ, Amaro MD, Cabrera D, Alvarez MC, Debeaufort F, Voilley A. Application of edible coatings to improve shelf-life of Mexican guava. Acta Horticulturae. 2003;589-594.
7. Udomkun P, Nagle M, Mahayothee B, Nohr D, Koza A, Müller J. Influence of air drying properties on non-enzymatic browning, major bio-active compounds and antioxidant capacity of osmotically pretreated papaya. LWT-Food Science and Technology. 2015;60(2):914-922.
8. Fernandes FA, Gallão MI, Rodrigues S. Effect of osmotic dehydration and ultrasound pre-treatment on cell structure: Melon dehydration. LWT-Food Science and Technology. 2008;41(4):604-610.
9. Oliveira SM, Brandão TR, Silva CL. Influence of drying processes and pretreatments on nutritional and bioactive characteristics of dried vegetables: A review. Food Engineering Reviews. 2016;8(2):134-163.
10. Pereira L, Ferrari C, Mastrantonio S, Rodrigues A, Hubinger M. Kinetic aspects, texture and color evaluation of some tropical fruits during osmotic dehydration. Drying Technology. 2006;24(4):475-484.
11. Izli N, Izli G, Taskin O. Drying kinetics, colour, total phenolic content and antioxidant capacity properties of kiwi dried by different methods. Journal of Food Measurement and Characterization. 2017;11(1):64-74.

12. Helvich K. Official methods of analysis. Association of Official Analytical Chemists; 1990.
13. Alibas I. Selection of the best suitable thin-layer drying mathematical model for vacuum dried red chili pepper. Journal of Biological and Environmental Sciences. 2012;6(17):161-170.
14. Trease G, Evans W. Pharmacology. 15th Edn. Saunders Publishers, London; 2002.
15. Mbatchou VC, Kosoono I. Aphrodisiac activity of oils from *Anacardium occidentale* L seeds and seed shells. Phytopharmacology. 2012;2(1):81-91.
16. Sofowora A. Medicinal plants and traditional medicine in Africa. Karthala; 1996.
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.
18. Slinkard K, Singleton VL. Total phenol analysis: Automation and comparison with manual methods. American Journal of Enology and Viticulture. 1977;28(1):49-55.
19. Ranganna S. Handbook of analysis and quality control for fruit and vegetable products. Tata McGraw-Hill Education; 1986.
20. Xiao HW, Yao XD, Lin H, Yang WX, Meng JS, GAO ZJ. Effect of SSB (superheated steam blanching) time and drying temperature on hot air impingement drying kinetics and quality attributes of yam slices. Journal of Food Process Engineering. 2012;35(3):370-390.
21. Chiralt A, Talens P. Physical and chemical changes induced by osmotic dehydration in plant tissues. Journal of Food Engineering. 2005;67(1-2):167-177.
22. Tsironi TN, Taoukis PS. Effect of processing parameters on water activity and shelf life of osmotically dehydrated fish filets. Journal of Food Engineering. 2014;123:188-192.
23. Vega A, Fito P, Andrés A, Lemus R. Mathematical modeling of hot-air drying kinetics of red bell pepper (var. Lamuyo). Journal of Food Engineering. 2007;79(4): 1460-1466.
24. Odenigbo U, Otisi C. Fatty acids and phytochemical contents of different coconut seed flesh in Nigeria. International Journal of Plant Physiology and Biochemistry. 2011;3(11):176-182.
25. Edeoga HO, Okwu D, Mbaebie B. Phytochemical constituents of some Nigerian medicinal plants. African Journal of Biotechnology. 2005;4(7):685-688.
26. Okwu D. Evaluation of chemical composition of indeginous species and flavouring agents. Global Journal of Pure and Applied Sciences. 2001;7(3):455-460.
27. Obidoa O, Joshua PE, Eze NJ. Phytochemical analysis of *Cocos nucifera* L. Journal of Pharmacy Research. 2010;3(2):280-286.
28. Brito-Arias M. Synthesis and characterization of glycosides. Springer. 2007;352.
29. Delanty N, Dichter MA. Antioxidant therapy in neurologic disease. Archives of Neurology. 2000;57(9):1265-1270.
30. Sabir SM, Hayat I, Gardezi SDA. Estimation of sterols in edible fats and oils. Pak J Nutr. 2003;2(3):178-181.
31. Bchir B, Besbes S, Karoui R, Attia H, Paquot M, Blecker C. Effect of air-drying conditions on physico-chemical properties of osmotically pre-treated pomegranate seeds. Food and Bioprocess Technology. 2012;5(5):1840-1852.
32. Osae R, Zhou C, Xu B, Tchabo W, Tahir HE, Mustapha AT, Ma H. Effects of ultrasound, osmotic dehydration, and osmosonication pretreatments on bioactive compounds, chemical characterization, enzyme inactivation, color and antioxidant activity of dried ginger slices. Journal of Food Biochemistry. 2019;43(5):e12832.
33. Garcia CC, Caetano LC, de Souza Silva K, Mauro MA. Influence of edible coating on the drying and quality of papaya (*Carica papaya*). Food and Bioprocess Technology. 2014;7(10):2828-2839.
34. El-Ishaq A, Obirinakem S. Effect of temperature and storage on vitamin C content in fruits juice. International Journal of Chemical and Biomolecular Science. 2015;1(2):17-21.
35. Blois MS. Antioxidant determinations by the use of a stable free radical. Nature. 1958;181(4617):1199-1200.
36. Nguyen ML, Schwartz SJ. Lycopene: Chemical and biological properties: Developing nutraceuticals for the new

millenium. Food Technology (Chicago). 1999;53(2):38-45.

37. Kammoun Bejar A, Kechaou N, Boudhrioua Mihoubi N. Effect of microwave treatment on physical and functional properties of orange (*Citrus sinensis*) peel and leaves. Journal of Food Processing & Technology. 2011;2(2): 109.

38. Maskan M. Drying, shrinkage and rehydration characteristics of kiwifruits during hot air and microwave drying. Journal of Food Engineering. 2001;48(2): 177-182.

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