RETENTION OF SIALIC ACID CONTENT IN MALAYSIAN EDIBLE BIRD'S NEST BY HEAT PUMP DRYING

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Abstract. This paper presents the results of an experimental attempt to improve the drying kinetics for the retention of colour and sialic acid in edible bird's nest through heat pump drying. Kinetics of hot air drying and heat pump drying were studied by performing various drying trials on edible bird's nest. Isothermal drying trials were conducted in hot air drying and heat pump drying at a temperature range of 40 °C-90 °C and 28.6 °C-40.6 °C, respectively. Intermittent drying trials were carried out in heat pump drying with two different modes, which are periodic air flow supply and step-up air temperature. Experimental results showed that heat pump drying with low temperature dehumidified air not only enhanced the drying kinetics but also produced a stable final product of edible bird's nest. Heat pump-dried edible bird's samples retained a high concentration of sialic acid when an appropriate drying mode was selected.

Keywords: edible bird's nest, heat pump drying, hot air drying, colour change, sialic acid retention

INTRODUCTION

Edible bird's nest (known in Chinese as "Yan Wo", Indonesia as "Sarang Walet" and Japanese as "Ensu") refers to the nest produced by several different swiftlet species. Edible bird's nest is considered a highly esteemed traditional and complementary medicine dating as far back as Tang (618-907 AD) and Sung (960-1279 AD) dynasties (Koon and Cranbrook, 2002). Health conscious consumers are seeking healthier natural food in order to have a nutritious diet. The two main functional components in edible bird's nest found by many researchers are sialic acid and epidermal growth factor (Konga *et al.*, 1987). A number of claimed benefits of consuming edible bird's nest, which includes dissolving phlegm, relieving gastric troubles, alleviating asthma, suppressing cough, curing tuberculosis, strengthening the immune system and accelerating recovery from illnesses and surgery (Konga *et al.*, 1987; Ma and Liu, 2012).

Colour plays an important role in appearance, processing and acceptability of edible bird's nests. In general, most of the raw edible bird's nests produced by the swiftlets are white in colour. Due to the exposure of the "blood bird's nest" incident which unveiled the entire edible bird's nest industry on adulterants, white edible bird's nest has become the highly recognized bird's nest colour in the market (Food Quality News, 2011). This in turn, has enhanced its commercial value. Nevertheless, bird's nest processing always results in browning, possibly due to high temperature or long duration of processing. This results in degradation of its optical quality.

Hence, this study hypothesized that the colour change of edible bird's nest can be reduced when the total drying time to achieve its equilibrium moisture content (at 10%-12%) is shortened and operating temperature is lowered. The choice of a suitable drying mode is equally as important as the selection of suitable dryer types in ensuring good product quality. As such, heat pump drying with two different modes – periodic air flow supply and step-up air temperature – has gained much attention in the edible bird's nest industry.

Sialic acid is a family of nine-carbon acidic monosaccharides occurring naturally at the end of sugar chains attached to the surfaces of cells and soluble proteins. N-acetylneuraminic acid (NANA) is one of the most predominant sialic acid occurring in nature (Shaw *et al.*, 2001). NANA residues of sialyl-sugar chains present in the edible bird's nest has been found to inhibit influenza virus infection (Guo *et al.*, 2006). Wang and Brand-Miller (2003) suggested that the exogenous source of sialic acid plays a role in brain development and learning ability. In Malaysia, sialic acid could be a potential criterion for determining the price of edible bird's nest (Marni *et al.,* 2014).

Although efforts have been made in investigating the drying characteristics in hot air drying, freeze drying, heat pump drying and low temperature drying on different types of food products, very little information is available in the comparison of these methods in terms of quality retention of edible bird's nest. The objective of this study was to investigate the effects of drying methods (hot air and heat pump drying), drying modes (periodic air flow supply and step-up air temperature) on drying kinetics as well as quality retention (colour change and sialic acid content) in edible bird's nest throughout the drying process.

MATERIALS AND METHODS

Sample Preparation

Fresh edible bird's nest was supplied by a bird's nest processing plant (LiZhi Trading) in Sungai Pelek, Selangor, Malaysia. Edible bird's nests with similar size (7-10 cm × 3.5-6 cm × 0.1-0.15 cm) and colour (L^*=56.9-57.2, a^*=0.7-0.8 and b^*=8.0-9.0) were selected for all experiments. The feathers in the bird's nest were cleaned by the workers with tweezers. In each experiment, the edible bird's nest was taken directly from the plant after the cleaning process, to avoid loss of moisture content.

Drying Methods

The edible bird's nest (about 14 g-20 g) was then placed on drying trays. The initial moisture content of fresh edible bird's nest was approximately 140%-210% (dry basis). The edible bird's nest was dried by different drying methods, which are described below, until equilibrium moisture content (EMC), 10%-12% dry basis was achieved.

Heat Pump Drying

The heat pump dryer was fabricated and supplied locally by I-Lab Sdn Bhd (Selangor, Malaysia). Figure 1 shows a schematic diagram of the dryer and its components. It consists of a heat pump system (broken lines) and drying chambers where meshed trays can be inserted to support the product. It was designed as

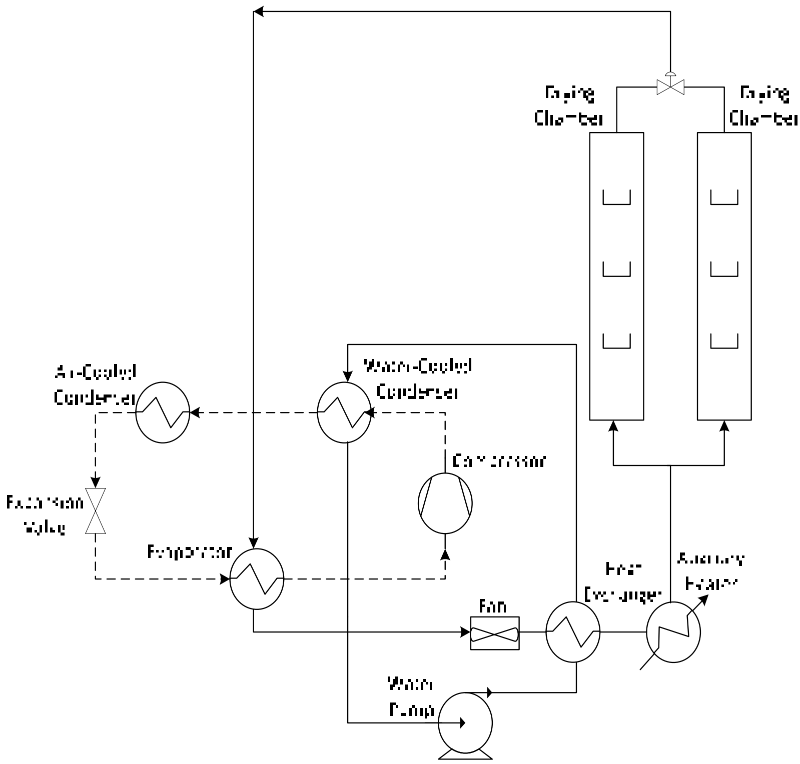

Figure 1. Schematic diagram of heat pump dryer that has shown its main components and process streams.

a closed loop system whereby the drying air is circulated within the drying system without any exchange with the surrounding air. A heater was installed before the drying chambers to further increase the drying air temperature. The overall dimensions (length × width × height) of the dryer were 0.23 m × 0.1 m × 0.2 m, while each drying chamber measured 0.33 m × 0.33 m × 0.98 m (Hii *et al.*, 2010).

Edible bird's nest was placed on a moulding tray of size 12 cm × 7 cm × 5 cm, perpendicular to air flow. The drying chamber was operated at drying temperature of 40.6 °C and 16.2% relative humidity (RH) when the heater was turned on, whereas the drying temperature was 28.6 °C and 26.7% RH when the heater was turned off. Average superficial air velocity in the chamber was 4.6 m/s. Air temperature and humidity were monitored using a data logger (Rotronic HW3, Hauppauge, New York, USA) and air flow was measured using a digital anemometer (Airflow LCA 30VT, North Yorkshire, UK) with accuracy ±0.01 m/s.

Two timer switches were installed on the control panel to set the changeover time of air flow between the drying chambers through diverter flaps that were actuated by compressed air. During the changeover, the on-line chamber experienced high air velocity (5.4 ± 0.5 m/s) and the off-line chamber experienced low air velocity (1.0 ± 0.5 m/s). By the special feature on the heat pump dryer, intermittent drying was performed.

Convective Hot Air Drying

Fresh edible bird's nest was dried in a laboratory scale hot air circulation oven (range 20 °C-250 °C, Memmert, Schwabach, Germany) with an accuracy of ±0.5 °C at air temperature of 70 °C with and without air circulation. The air circulation was set at a velocity of 4.6 m/s. Prior to drying experiments, the oven was turned on at the selected operating conditions. The total drying time to achieve EMC was 8 hrs for oven drying without air circulation and 6 hrs for drying with air circulation.

Drying Procedure and Measurements

Fresh edible bird's nest samples were subjected to convective hot air drying, low temperature drying and assisted by infrared and UVC treatment, heat pump drying and freeze drying. Weight loss of the sample was monitored using an analytical balance (JS303G, Mettler Toledo, Switzerland). The weight of the same sample was recorded periodically at 5-min intervals in the first 60 minutes and 30-min intervals thereafter until a constant reading was obtained in three consecutive measurements. The moisture content of the sample at this stage was marked as the equilibrium moisture content (EMC). Temperature and relative humidity in the drying chamber were determined using a data logger Rotronic hygrometer (RS232, HygroFlex, Hauppauge, NJ), which was equipped with digital probes and HW3 software. Air flow was measured with an anemometer (LCA30VT, Airflow, Buckinghamshire, UK) with accuracy ±0.01 m/s and water activity of the dried sample was measured using a water activity meter (Decagon, Pawkit, Pullman, WA). Dry matter weight (d_w) was determined by drying the sample in an oven at 105 °C for 24 hrs.

Repeatability and Reference Analysis

Each drying experiment was conducted in three replicates. Average values were obtained. Samples dried using convective hot air drying was used as reference samples for the comparison with samples dried by continuous and intermittent heat pump drying in terms of colour change and nitrite content change in dried edible bird's nest and energy saving.

Determination of Moisture Content

Moisture content was calculated from the initial moisture content and the mass loss, assuming that the mass loss is only due to loss of moisture. The moisture content (MC) of the edible bird's nest was determined with reference to the bone-dry weight of the nests, determined by the oven drying method (Equation 1) (Hii *et al.*, 2010). The final moisture content was targeted as 10%-12% (dry basis) and the drying kinetics were plotted. For the purpose of graphical presentation the moisture ratio was defined based on the moisture content (Equation 2) (Hii *et al.*, 2010).

$$MC\left(\frac{g\,H_2O}{g\,dry\,solid}\right) = \left[\frac{W_o - W_d}{W_d}\right] \quad (1)$$

Where W_o is the initial weight of product (g) and W_d is the weight of dry matter in product (g).

$$Moisture\ ratio, MR = \frac{X_i - X_e}{X_o - X_e} \quad (2)$$

Where X_i is the moisture content at time i, X_e is the equilibrium moisture content and X_o is the initial moisture content.

Colour Analysis

During drying, bird's nest samples will be removed from the dryer after reaching equilibrium moisture content for colour measurements by using a colorimeter (AccuProbe, HH06, USA) in a room with controlled light. The instrument was calibrated before the experiments with a white ceramic plate. The bird's nest samples were scanned at three different locations to determine the average CIE *L*, a* and b** values during the measurements. The total colour change, Δ*E*, (Equation 3) and chroma (Equation 4) (Dadali *et al.*, 2007) were calculated from the CIE *L*, a** and *b** scale and was used to describe the colour change during drying.

$$\Delta E = \sqrt{(L^*_0 - L^*_t)^2 + (a^*_0 - a^*_t)^2 + (b^*_0 - b^*_t)^2} \quad (3)$$

Where L^*_o, a^*_o and b^*_o are the initial colour measurements of raw bird's nest samples and L^*_t, a^*_t and b^*_t are the colour measurements at a pre-specified time.

$$Chroma = (a^{*2}_t + b^{*2}_t)^{0.5} \quad (4)$$

Sialic Acid Analysis

The sample treatment and the analysis of the raw edible bird's nest samples were performed as described by Yu *et al.* (2000) with some modifications. Ten mg of crushed dried raw edible bird's nest was weighed, and the sample was put into a glass vial with a Teflon sealing screw for derivatization. After 0.5 mL of 1M sulphuric acid-methanol was added, the vial was filled with nitrogen gas and closed tightly. Then the vial was heated in an oven for 90 min at 90 °C. After the vial was cooled to room temperature, the reactant in the vial was transferred into a centrifuge tube, and 0.3 g of barium carbonate was added to neutralize the sulphuric acid in the solution. The tube was placed on an ultrasonic vibrator for 5 minutes. The sample was then centrifuged at 4500 rpm for 5 min and the supernatant was further centrifuged at 14,000 rpm for 6.5 min. The supernatant was transferred into a test tube with a ground-glass cover. The tube was vacuumed at approximately 35 °C to evaporate the methanol (Yu *et al.*, 2000).

For acetylation, the dried sample was thoroughly shaken and stirred with 1 ml of 1M pyridine and 0.5 ml of 1M acetic anhydride, and then incubated at 90 °C for 30 min. Sample solution was centrifuged at 14,000 rpm for 10 min during cooling, and the sample was subsequently injected into an HPLC for analysis after 1 hour. The sialic acid content was analyzed using an Agilent 1200 Series HPLC with RI detector for detection. The separation was performed on Agilent Hi-Plex H column (7.7 mm × 300 mm, 8 µm film thickness) with gradient elution of 0.005M sulphuric acid. The operating conditions were: injection port temperature, 100 °C; interface temperature, 70 °C; column compartment temperature, 60 °C; 0.005M of sulphuric acid (flow rate of 0.5 ml/min at 60 °C and 50 bar; 0.4 µL injection volume. The injector was operated in the splitless mode for 1 min after injection of the sample (Yu *et al.*, 2000).

Five monoses: D-Mannose (Man), D-Galactose (Gal), N-Acetyl-D-galactosamine (AcGal), N-Acetyl-D-glucosamine (AcGlu), and N-Acetyl-neuraminic acid (also called sialic acid, NaNa), that were derived from the oligosaccharides components of fresh edible bird's nest were employed as standards. All the standard chemicals employed was of HPLC grade and was purchased from Sigma (St. Louis, USA). Identification of compounds was achieved by comparing the mass spectra and retention times of the chromatograph peaks with those of standards. For quantification, the internal standard method was introduced to compensate the potential sources of errors during sample detection. Calibration curves of the five monoses were obtained from the concentration ratio versus the corresponding peak area ratio of each oligosaccharides to internal standard. Each determination was carried out in triplicate.

RESULTS AND DISCUSSION

Drying Characteristics of Intermittently Heat Pump Dried Edible Bird's Nest

Effect of Drying Method

Drying kinetics of edible bird's nest were studied by performing hot air drying at four temperature levels (40 °C-90 °C) that are commonly used in drying of agricultural products (Ong and Law, 2011). In order to study the effects of relative humidity on drying kinetics, drying medium in heat pump drying was manipulated to temperatures that were similar to and lower than those used in hot air drying. Water activity (a_w), equilibrium moisture content (EMC), and total drying time in accordance with drying conditions were concluded in Table 1.

The results (Figure 2) showed the exponential decrement in residual moisture ratios for both hot air drying and heat pump drying. It was observed that hot air drying at 90 °C and heat pump drying at 40.6 °C reduced the drying time by approximately 82% and 73% compared to at 40 °C and 28.6 °C, respectively. It can be seen in Figire 3 that the drying rates of both hot air and heat pump drying significantly increased with drying temperature. As expected, air temperature is always the main key that significantly influences the drying rate. This is because elevated temperature increases the driving force of

Table 1. Water activity (a_W), EMC and total drying time in accordance with the drying conditions.

Drying System	Remarks	T (°C)	RH (%)	v (m/s)	Time (h)	EMC (% db)	a_W
Hot Air Drying							
HA40		40	34	1.0	10.0	11.82	0.55
HA50		50	24	1.0	9.5	11.27	0.53
HA70		70	10.1	1.0	9.5	11.45	0.52
HA90		90	2.2	1.0	7.0	11.09	0.51
Heat Pump Drying							
HP1		28.6	26.7	5.4	10.5	11.15	0.56
HP2		40.6	16.2	5.4	9.0	11.41	0.48
HP1HP2	Initial Stage	28.6	26.7	5.4	8.5	10.48	0.52
	Final Stage	40.6	16.2	5.4			
HP2HP2	High Air Flow	40.6	16.2	5.4	8.5	11.12	0.51
	Low Air Flow	39.0	18.5	1.0			

heat transfer to sample, thus resulting in rapid evaporation and high diffusion rate of moisture in the sample and consequently shortening the drying time (Arroqui *et al.*, 2002; Ramesh *et al.*, 2001).

However, the temperature must not exceed a certain limit in drying of biological products because that may result in some adverse effects on the quality of the final products such as the retention of sialic acid in the edible bird's nest. On the other hand, when comparing drying rates between hot air and heat pump drying, it was observed in Figure 3. that drying rate

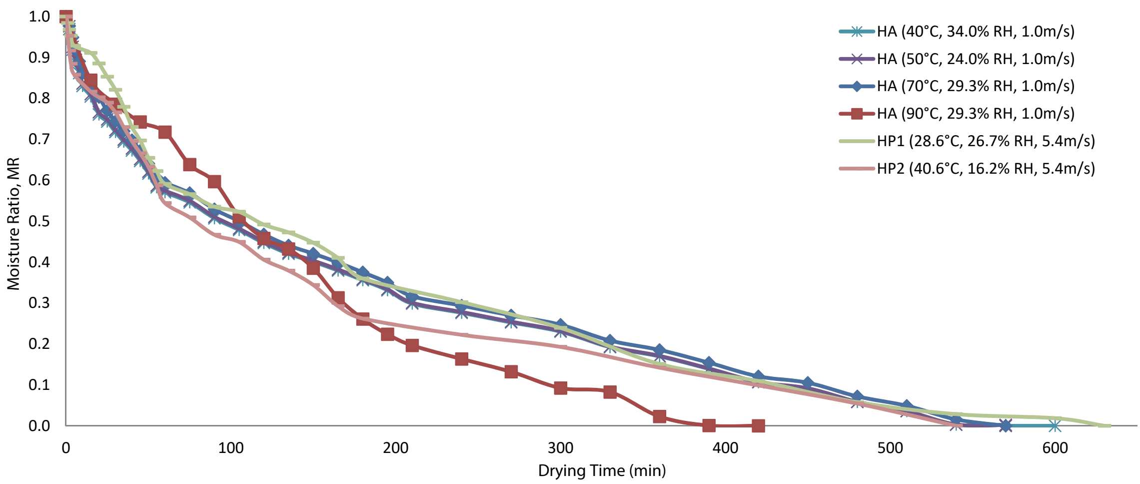

Figure 2. Variation of moisture ratios with time in hot air drying and heat pump drying at different temperature.

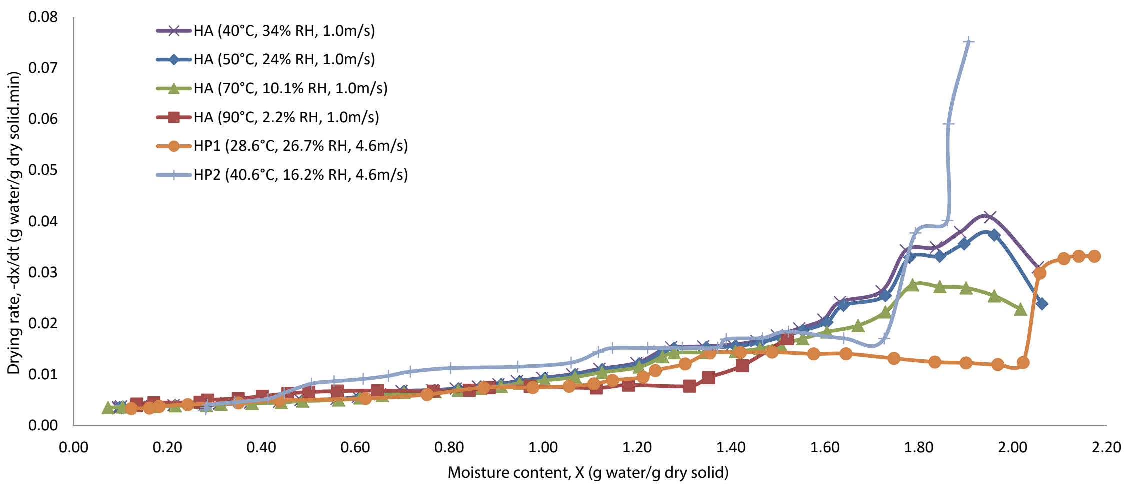

Figure 3. Drying rate curves of hot air drying and heat pump drying at different temperatures.

of HP2 was higher than HA40. Apparently, apart from drying temperature, air relative humidity plays an important role as well in influencing the drying rate. Lowering total water pressure in the drying air would create a greater driving force for moisture removal on the solid surface, hence increasing the drying rate (Jangam *et al*., 2008).

In the present study, initial transient periods were observed in the drying rates of hot air drying before it reached the highest drying rate but they did not exist in the heat pump drying. This could be due to the higher air velocity used in the heat pump drying compared to hot air drying. Convective heat transfer to the sample could be enhanced by drying with high air flow, in order to reach the desired product temperature and moisture removal from the surface of the product in the initial stage of drying (Chin *et al*., 2009; Yaldyz *et al*., 2001).

Effect of Intermittent Drying

Two intermittent modes were employed in the present study, step-up air temperature (HP1HP2) and periodic heat air flow supply (HP2HP2), as shown in Figure 4. Both intermittent profiles have been reported to be efficient in preserving heat-labile materials (Chua *et al*., 2001). In HP1HP2 mode, a relatively low temperature (28.6 °C) was used in the initial stage of drying (the first 180 min) and the drying temperature was increased to 40.6 °C thereafter until the sample reached its equilibrium moisture content. While, in HP2HP2 mode, high air velocity (5.4 ± 0.5 m/s) was used in the initial stage and

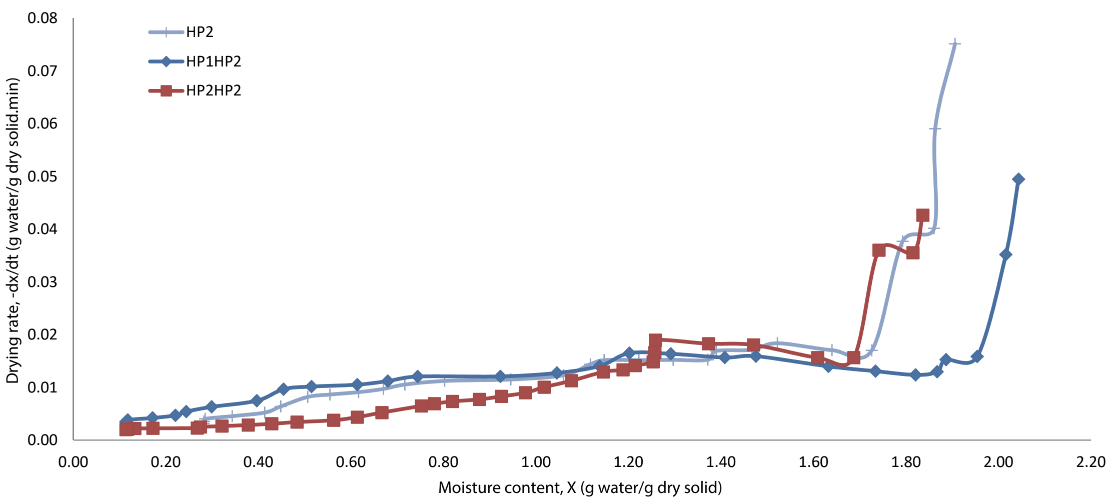

Figure 4. Drying rate curves of heat pump intermittent drying with step-up temperature mode (HP1HP2) and periodic air flow supply (HP2HP2).

decreased to 1.0 ± 0.5 m/s thereafter until the sample reached its EMC.

It was observed that drying time was longer using HP2HP2 mode compared to the HP1HP2 mode. Although the moisture content in the sample under isothermal drying (HP2) decreased faster in the initial stage of drying, the drying time was slightly longer than that in step-up temperature mode (HP1HP2). It can be seen that the drying rate of HP2HP2 mode was higher than HP1HP2 in the early stage of drying when the moisture content was still high. However, drying rate decreased significantly when the forced air flow was halted in the second hour of drying. Hence, the results suggest that forced air is important in the initial stage of drying in order to speed up the drying process, and intermittent forced air supply can be advantageous in the later stage of food drying.

Besides, for HP1HP2 mode, it can be observed that the drying rate was relatively high at the beginning of drying but decreased with time thereafter. The higher temperature used in the second stage of drying increased the drying rate for at least 1 hour before it decreased again with time until the end of drying. Nevertheless, the total drying time of the HP1HP2 mode was observed to be shorter than isothermal drying (HP2) mode. It is interesting to observe that the absence of heat flux in the interim period of drying not only improved the drying rate but allowed a tempering period for the food sample as well (Ong and Law, 2011).

As suggested by Ong and Law (2011), heating can be interrupted temporarily at some stage of drying to allow moisture to transfer from inner core of the food matrix to the exposed surface. Intermittent heat supply during food drying controlled by internal moisture diffusion will not only avoid overheating of the material surface (without improvement in drying rate) but will also minimize the degradation of heat-labile bio-ingredients and product shrinkage (Ong and Law, 2011).

Colour Analysis of Edible Bird's Nest

Colour parameters CIE L^*, a^* and b^* values and other derived parameters such as total colour change (ΔE) and chroma for different drying methods were calculated using Equations 3 and 4, and the results were shown in Table 2. There was no significant difference in terms of CIE L^* and a^*($p > 0.05$) among the hot air and heat pump dried products. The values showed that intermittent heat pump dried product at α=0.2 for both drying at 28.6 °C and 40.6 °C had the lowest b^* value compared to fresh edible bird's nest. This indicates that the samples maintained the original yellowish colour and less browning.

The total colour change (ΔE) of hot air dried edible bird's nest at drying temperature of 40 °C-90 °C was 9.70 and 29.52, respectively, which were higher than heat pump dried edible bird's nest at 40.6 °C and 28.6 °C, at every intermittency. Heat pump drying of edible bird's nest at 28.6°C reduced the overall colour change

Table 2. Colour parameters of intermittent heat pump dried edible bird's nest compared to those obtained using continuous heat pump and hot air drying treatments.

Drying methods	Colour Parameters			Total Colour Change, ΔE	Chroma
	L^*	a^*	b^*		
Fresh Edible Bird's Nest	58.7 ± 2.62[a]	0.80 ± 0.21[a]	12.1 ± 2.85[b]		12.08 ± 2.21[de]
Hot Air Drying					
at 40 °C and 34.0% RH	62.9 ± 1.64[b]	0.70 ± 0.20[a]	15.7 ± 3.01[bc]	9.70 ± 3.64[d]	15.71 ± 3.37[bcd]
at 50 °C and 24.0% RH	71.2 ± 1.23[c]	0.80 ± 0.15[a]	17.8 ± 6.58[bc]	13.76 ± 2.85[b]	17.82 ± 3.13[de]
at 70 °C and 10.1% RH	75.9 ± 2.59[b]	0.70 ± 0.28[a]	25.7 ± 9.56[bd]	21.96 ± 1.47[ab]	25.71 ± 4.75[bd]
at 90 °C and 2.2% RH	76.5 ± 1.09[b]	0.80 ± 0.39[a]	35.6 ± 5.21[bc]	29.52 ± 5.96[ab]	35.61 ± 5.99[bd]
Heat Pump Drying at 40.6 °C and 16.2% RH					
α = 0.20	60.2 ± 0.22[ab]	0.80 ± 0.07[a]	16.9 ± 3.46[ab]	5.08 ± 4.04[ac]	16.92 ± 5.63[bcd]
α = 0.33	62.7 ± 0.24[c]	0.70 ± 0.24[a]	18.0 ± 5.43[a]	7.17 ± 1.26[ab]	18.01 ± 0.90[cde]
α = 0.67	61.3 ± 1.03[bc]	0.80 ± 0.12[a]	17.5 ± 1.22[a]	6.04 ± 5.21[bc]	17.52 ± 1.72[bd]
α = 1.00 (Continuous)	67.6 ± 2.02[bc]	0.70 ± 0.22[a]	24.1 ± 1.65[cd]	14.98 ± 3.19[bc]	24.11± 1.83[c]
Heat Pump Drying at 28.6 °C and 26.7% RH					
α = 0.20	59.6 ± 1.54[bc]	0.80 ± 0.09[a]	16.7 ± 0.92[bcd]	4.74 ± 5.02[bcd]	16.72 ± 0.15[acd]
α = 0.33	61.5 ± 1.29[ab]	0.70 ± 0.20[a]	17.2 ± 1.65[bc]	5.86 ± 1.87[bc]	17.21 ± 2.69[bcd]
α = 0.67	60.4 ± 1.84[bc]	0.70 ± 0.14[a]	19.9 ± 5.91[bcd]	8.03 ± 3.26[c]	19.91 ± 5.71[ce]
α = 1.00 (Continuous)	65.4 ± 0.75[bc]	0.70 ± 0.11[a]	21.4 ± 2.54[bc]	11.50 ± 2.55[ab]	21.41 ± 3.30[de]

Mean values ± standard deviation (n = 3 replications) within the same column with the same letter are not significantly different (p >0.05).

(up to 42%) compared to hot air drying (with and without air circulation) and heat pump drying at 40.6 °C under all drying conditions. It was reported that low-temperature dehumidified air and short effective time throughout the drying process in a heat pump dryer reduced the extent of the non-enzymatic browning reaction, which is consistent with the findings of Perera and Rahman (1997) and Jangam *et al.* (2008).

Besides, during tempering period, lower temperature and relative humidity operated in the drying chamber also have a significant effect in the reducing the colour change of edible bird's nest due to non-enzymatic browning. These findings are consistent with the reference of Chua *et al.* (2001, 2002), Chin and Law (2010) and Ho *et al.* (2002). Non-enzymatic browning or Maillard reaction, is often the limiting factor of dehydrated foods. Parameters affecting the Maillard reaction are primarily drying temperature and the duration of the heat treatment (Marty-Audouin, Leber and Rocha-mier, 1999). Moreover, compared to continuous heat pump dried products, intermittent heat pump drying of edible bird's nest at 28.6 °C reduces the overall colour change from 42%-76% for α=0.20, α=0.33 and α=0.67, whereas the reduction of colour change is more prominent for intermittent heat pump-dried product at 28.6 °C and 26.7% RH, which is up to 76% at α=0.20.

During the tempering period, the moisture from the centre of the material is redistributed to the surface which probably prevented dehydration of the surface and hence reduced the rate of Maillard reaction, lowering the overall colour change. Therefore, intermittent low dehumidified air drying offers new dimension in transient drying to reduce colour degradation without too much compromise on drying time (Chua *et al.,* 2001).

Sialic Acid Content of Edible Bird's Nest

With the established oligosaccharides and fingerprint of edible bird's nest by HPLC, the effect of conventional and advanced drying methods on the retention of sialic acid can be identified. The content of NANA (in measuring sialic acid content) was established as unique indicators for the grades of real edible bird's nest. Changes of sialic acid content in edible bird's nest samples from the various drying experiments was recorded. Figure 5 shows that the sialic acid content of all heat pump-dried samples are higher than

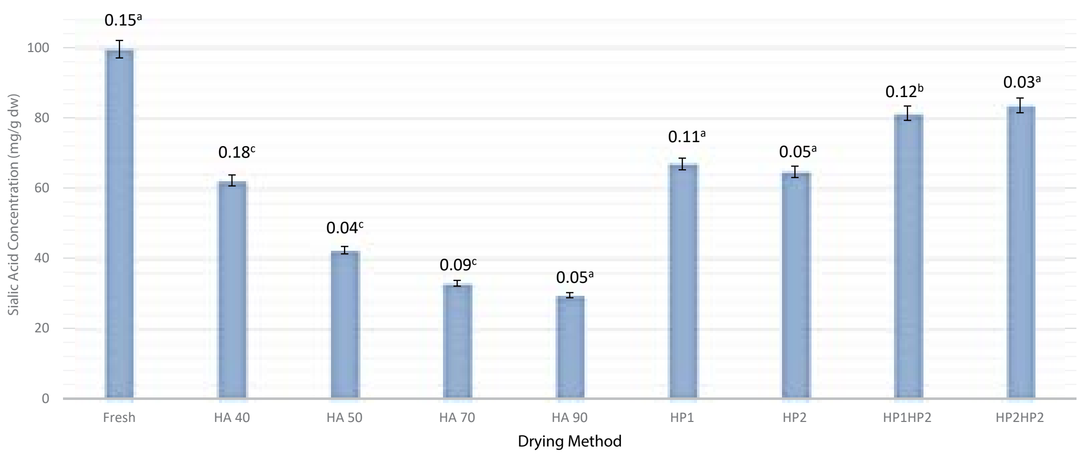

Figure 5. Sialic acid content in edible bird's nest after dried by different drying methods and modes.

hot air-dried samples at relatively high drying temperature. It was also observed that the sialic acid content of samples that were dried by heat pump drying at 28.6 °C, 26.7% RH and 40.6 °C, 16.2% RH, respectively, were even higher than samples that dried at hot air drying at 40 °C, 34% RH.

It was also observed that intermittent mode drying using both modes, HP1HP2 and HP2HP2, retained higher sialic acid content compared to continuous drying (HP1 and HP2 modes), whereas the high temperature (40 °C-90 °C) used in hot air drying degraded the sialic acid drastically as compared to heat pump-dried samples. The results depict that the loss of sialic acid in edible bird's nest could be attributed to a combination of the effects of thermal degradation and enzymatic oxidation due long drying time. Intermittent low temperature drying may prevent the thermal degradation of sialic acid but excessive drying time may trigger enzymatic oxidation. In contrast, drying at high temperature may significantly shorten the drying time and hence reduce the enzymatic oxidation but may cause severe thermal degradation (Chin and Law, 2010; Saito and Nakanishi, 1975).

Another reason for the great loss of sialic acid content under high drying temperatures is the loss of stabilizing activity in molecular structures of sialic acid according to the progression of thermal degradation of sialic acid molecules. The alteration of sialic acid molecules subjected to relatively high heat treatment, is highly dependent on the ionic environment, and is considered to be due to intermolecular aggregation probably involving disulfide bonds and perhaps also hydrogen and hydrophobic bonds. Under severe heat treatments > 60 °C, the incidental structural alteration or association becomes difficult because of partial degradation of sialic acid molecules (Department of Veterinary Services, 2009; Khalifa *et al.*, 1985; Shah and Shukla, 1975).

Apparently, heat pump drying takes advantage of their ability to generate dehumidified air at low temperatures, which allows rapid drying at low temperatures and thus better preservation of sialic acid. Results suggested that drying temperature (< 40 °C) is sufficiently low to minimize thermal destruction of sialic acid presents in the bird's nest.

CONCLUSIONS

Apparently, the drying kinetics of edible bird's nest increased with increasing temperature and decreasing relative humidity in the drying medium. However, drying temperature could not be too high because that would cause thermal degradation of heat-labile bio-ingredients such as sialic acid. It was also observed that the effects of relative humidity and air velocity on the drying rate were significant when the moisture content in edible bird's nest sample was high, whereas the effects of temperature predominated at low moisture content.

On the other hand, reduction of sialic acid content in edible bird's nest during drying could be attributed to thermal degradation and enzymatic oxidation. Drying at high temperature (70 °C-90 °C) and long drying time significantly reduced the amount of sialic acid. The effects of high temperature (> 40 °C) on retention of sialic acid were apparent but drying at temperature below 37 °C produced final products with higher sialic acid.

REFERENCES

1. Arroqui C., Rumsey T.R., Lopez A. and Virseda P. (2002). Losses by diffusion of ascorbic acid during recycled water blanching of potato tissue. *Journal of Food Engineering*, **52**: 25-30.
2. Chin S.K. and Law C.L. (2010). Product quality and drying characteristics of intermittent heat pump drying of *Ganoderma tsugae* Murril,. *Drying Technology.* **28(12)**: 1457-1465
3. Chin S.K., Law C.L., Supramaniam C.V. and Cheng P.G. (2009). Thin layer drying characteristics and quality evaluation of air-dried *Ganoderma tsugae* Murrill. *Drying Technology,* **27(9)**: 975-984.
4. Chua K.J., Mujumdar A.S., Hawlader M.N.A., Chou S.K. and Ho J.C. (2001). Batch drying of banana pieces – effect of stepwise change in drying air temperature on drying kinetics and product colour. *Food Research International*, **34(8)**:721-731.
5. Chua K.J., Hawlader M.N.A., Chou S.K. and Ho J.C. (2002). On the study of time-varying temperature drying-effect on drying kinetics and product quality. *Drying Technology*, **20(8)**:1559-1577.
6. Dadali G., Kilic A.D. and Ozbek B. (2007). Colour Change Kinetics of Okra Undergoing Microwave Drying. *Drying Technology*, **25(5)**:925-936.
7. Department of Veterinary Services (2009). Code of Good Veterinary Hygienic Practice (GVHP for EBN) on Processing of Raw Clean Edible Bird's Nests (EBN).
8. Department Standard Malaysia (DSM) (2011). Edible Bird Nest (EBN) Specification. MS 2334:2011.
9. Food Quality News (2011). *China finds nitrite in edible bird's nest from Malaysia.* Available at: http://www.foodqualitynews.com/Public-Concerns/China-finds-nitrite-in-edible-bird-s-nests-from-Malaysia (Accessed on November 20, 2013).
10. Guo C.T., Takahashi T., Bukawa W., Takahashi N., Yagi H., Kato K., Hidari K.I.P.J., Miyamoto D., Suzuki T., and Suzuki Y. (2006). Edible bird's nest extract inhibits influenza virus infection. *Antiviral research*, **70(3)**:140-6.
11. Hii C.L., Law C.L., Michael C. and Suzannah S. (2011). Improving Malaysian cocoa quality through the use of dehumidified air under mild drying conditions. *Journal Science of Food Agriculture*, **91:** 239-246.
12. Ho J.C., Chou S.K., Chua K.J., Mujumdar A.S. and Hawlader M.N.A. (2002). Analytical study of cyclic temperature drying: effect on drying kinetics and product quality. *Journal of Food Engineering,* **51(1)**: 65-75.
13. Jangam S.V., Joshi V.S., Mujumdar A.S. and Thorat B.N. (2008). Studies on dehydration of sapota (*Achras zapota*). *Drying Technology,* **26(3)**:369-377.
14. Khalifa M.Y., Niki R. and Arima S. (1985). Effect of heat treamtnets on k-casein. *Hokkaido University Collection of Scholarly and Academic Papers*, **62(3):**282-301.
15. Konga Y.C., Keunga W.M., Yipa T.T., Koa K.M., Tsao S.W. and Ng M.H. (1987). Evidence that epidermal growth factor is present in swiftlet's (Collocalia) nest. *Comparative Biochemistry and Physiology B*, **87(2):**221-226.
16. Ma F.C. and Liu D.C. (2012). Sketch of the edible bird's nest and its important bioactivities. *Food Research International* **48:** 559-567.
17. Marni S., Marzura M.R., Norzela A.M., Khairunnisak M., Bing C.H. and Eddy A.A. (2014). Preliminary Study on Free Sialic Acid Content of Edible Bird's Nest from Johor and Kelantan. *Malaysian Journal of Veterinary Research,* **5(1):**9-14.
18. Marty-Audouin C., Leber A. and Rocha-mier T. (1999). Influence of drying on the colour of plant products. *Developments in drying: food dehydration*, **1:**207-234.
19. Ong S.P. and Law C.L. (2011). Drying Kinetics and Antioxidant Phytochemicals Retention of Salak Fruit under Different Drying and Pretreatment Conditions. *Drying Technology* **29(4):** 429-441.
20. Perera C.O. and Rahman M.S. (1997). Heat pump dehumidified drying of food. *Trends in Food Science and Technology*, **8:**75-79.
21. Ramesh M.N., Wolf W., Tevini D. and Jung G. (2001). Influence of processing parameters on the drying of spic paprika. *Journal of Food Engineering*, **49(1):**63-72.
22. Saito T. and Nakanishi T. (1975). Degradation of k-casein by heating at higher temperatures. *Jap. J. Dairy Sci,* **24(A):**181-193.
23. Shah P.K. and Shukla P.C. (1975). Heat induced changes on levels of bound sialic acid and hexose of whole acid and k-caseins obtained from milk of Kankrej and Jersey cows [India]. *Gujarat Agricultural University. Res. J.*, **1:**78-82.
24. Shaw C.J., Chao H. and Xiao B.M. (2001). Determination of sialic acids by liquid chromatography-mass spectrometry. *J. Chromatogr,* **913(1-2):** 365-370.

25. Yaldyz O. and Ertekyn C. (2001). Thin layer solar drying of some vegetables. *Drying Tech*, **19(3):**583-597.
26. Yu Y.Q., Xue L., Wang H., Zhou H.X., Zhu X.F. and Li B.S. (2000). Determination of edible bird's nest and its product by gas chromatography. *Journal of Chromatography Science,* **38:**1-6.

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