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Optimisation of Microwave Drying for Encapsulation of Edible Bird's Nest Hydrolysate

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There has been limited study on the encapsulation of edible bird's nest (EBN) employing microwave drying and the evaluation of the final product quality. This study aimed to optimise the encapsulation of EBN hydrolysate (EBNH) using microwave drying by optimising microwave power, encapsulation time and core-to-wall (C/W) ratio. Physiochemical properties of encapsulated EBNH were measured. Response surface methodology (RSM) using Box Behnken design was used to optimise the conditions of microwave power, encapsulation time and C/W ratio by using Design Expert 13 software. Based on the colour analysis, the value of chroma obtain was 5.062 ± 0.93 while the degree of hue obtained from the optimum condition was 40.696 ± 3.85º. The moisture content obtained from the optimum condition was 10.59 ± 0.49 %. The moisture content attained was in the range of the dry basis targeted in this study which is in between 5 – 12 % dry basis. Dissolution time obtained from the optimum condition was 126 ± 24.67 s. Solubility percentage shows that EBNH powder encapsulated with maltodextrin treatment has a high degree of solubility, reaching up to 92.5 %. This shows that the optimum condition was significant in terms of the powder solubility that was attained. High DPPH activity (48.83 ± 0.95 %) was obtained that showed that EBNH possessed strong antioxidant effects. In conclusion, C/W ratio were found to significantly affect degree of hue, chroma value and solubility of the powder. The encapsulation time during microwave was found to affect the dissolution time, DPPH assay and moisture content.

1. Introduction

Drying is often required for postharvest processing of agricultural, herbal, food product, and biomaterial products. This procedure is essential in order to minimise the moisture content to a degree that is suitable for storage while also preventing the growth of moulds and bacteria (Fabiano et al., 2010). It is also necessary in processing industry to dry swiftlet edible bird's nest (EBN) in order to limit the water activity to achieve these goals. Consumer expectations for improved quality, safety and nutritional value in EBN are the reasons that driving the development and enhancement of EBN drying technologies. According to Ling et al. (2020), when compared to raw EBN, EBN hydrolysates (EBNH) had a significantly greater soluble protein concentration of up to 9 %. It also has greater solubility that helps in increasing its functionality, digestibility and bioactivity.
Encapsulation is a method of preventing chemical reactions and facilitating the controlled release of the core bioactive substance from the shell coating of single or combination of shell materials. Microwave-assisted drying is one of the green technologies which has been utilised for encapsulation of various food products and bioactive compounds such as anthocyanins (Jusoh et al., 2018) and mulberry extract (Ahmad et al., 2020). Microwave has many advantages in drying of food products since it permeates food and heat both the outer surface and interior sides, allowing in a quicker drying process and improved end product quality (Samad et al., 2021).
The wall material used for encapsulation should be simple to work with and provide optimum protection for the core substance. The inclusion of some encapsulating agents to microwave-assisted powders might face some

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issues such as adhesion and hygroscopicity. Maltodextrin is the most widely used encapsulating agent to overcome these issues as it is an excellent binder and stabiliser (Cano-Chauca et al., 2005). It also offers slow viscosity, good biocompatibility and high-water solubility in encapsulation of bioactive compounds. Due to these reasons, maltodextrin was used in this study as the wall material. The objective of this study mainly focused on optimisation and characterisation of encapsulated EBNH using microwave drying at different encapsulation time, microwave power and varying concentrations of maltodextrin (MD) as wall material.

2. Materials and methods

Liquid edible bird's nest hydrolysate (EBNH) was obtained from Innovation Center for Confectionery Technology, Universiti Kebangsaan Malaysia and analytical-grade maltodextrin (MD) (Dextrose Equivalent: 4.0-7.0; Sigma Aldrich, US) was purchased from a supplier in Shah Alam, Selangor.

2.1 Experimental design

Response Surface Methodology (RSM) using the Box Behnken Design was used to optimise the encapsulation time, microwave power and C/W ratio for encapsulation of EBNH via Design Expert 13 software. Table 1 shows the selected factors and its level for the experiment. 15 factorial experiments with three repetitions each were conducted for the experimental design.

Table 1: Factors and levels of experiment

Factor	Factor Name	Factor Level		
		-1	0	1
Time, min	A	5	7.5	10
Power, W	B	500	625	750
Core-to-wall ratio (C/W), w/w	C	1:1	1:5.5	1:10

2.2 Encapsulation of EBNH using microwave drying

Encapsulation method was done accordance to Ahmad et.al (2020) with some modifications. Using an IKA T-25D Ultra-Turrax homogenizer (Germany), the mixture of MD and EBNH with different C/W ratios was homogenised to obtain a uniform dispersion at 8,000 rpm for 10 min. The mixtures were placed in spherical glass plates and heated in a domestic microwave oven (R774AST, Sharp, Japan) for the encapsulation procedure. After that, the solutions were dried and encapsulated with different time and power settings in accordance with the randomised run, as shown in Table 2. Using a freeze-dryer (LBFD-A10, United Kingdom), the solutions were frozen at -60 °C and dried at -40 °C for 48 h. The freeze-dried mixtures were ground using a mortar until a uniform particle size was achieved. The sample was analysed for its physicochemical properties.

2.3 Colour analysis

Colour analysis was done in accordance to Jusoh et al. (2018). A portable Minolta CR-410 colorimeter (Konica Minolta, Japan) was used to calculate the values of L*, a*, and b* for the EBNH sample using the International Commission on Illumination (CIE) system L* (brightness), a* (redness), and b* (brightness) (yellowness). A white tile was used to pre-calibrate the chromameter (L*:90.83, a*:4.81, b*: -1.16). The colour of the EBNH samples were evaluated based on values of chroma, C* and hue angle, H°. The values of C* and H° were calculated using the values of a* and b* obtained using the formula in Eq(1) and Eq(2).

$$C^* = (a^{*2} + b^{*2})^{\frac{1}{2}} \tag{1}$$

$$H^o = tan^{-1}\frac{b^*}{a^*} \tag{2}$$

2.4 Moisture content

Moisture content was done in accordance to Putri et al. (2015). The moisture content was measured using MX-50 Moisture Analyzer (MX-50, A&D Company, Japan). Each sample was measured at 0.5 g and the analysis was carried out in triplicate.

2.5 Dissolution test

Dissolution test was done in accordance to Mohd Nawi et al. (2015) with some modifications. At moderate speed, vortex mixer (ZX3 advanced vortex mixer, VELP Scientifica Srl, Italy) was used to blend the solution. It was timed on how long it took for the powder to dissolve in water. The test was carried out in triplicate.

2.6 Solubility

The solubility was determined according to the method by Cano-Chauca et al. (2005) with some modifications. 1.5 g of sample was mixed with 100 mL of distilled water and the mixture was stirred in a magnetic stirrer (FAVORIT Magnetic Stirrer, PLT Scientific Sdn Bhd, Malaysia) for 30 min. The sample was centrifuged (Universal 320 R Benchtop Centrifuge, Hettich, Germany) for 5 min. Aliquot of 25 mL of supernatant was transferred to pre-weighed petri dish and oven-dried (Memmert UM 400 Drying Oven, Memmert, Germany) immediately at 105 °C for 5 h. The solubility was calculated by weight difference and expressed in %.

2.7 Antioxidant activity

Antioxidant activity was determined by referring to Ling et al. (2020) with some modifications. 2.36 mg of DPPH powder was mixed with 60 mL ethanol to get 0.1 mM concentration. In a 250 mL conical flask, 1 mL of the EBNH extract was mixed with 6 mL ethanol and 3 mL of DPPH solution. To avoid light exposure, the conical flask was completely covered in aluminium foil. After vigorous shaking, the mixture was set aside at room temperature for 30 min in a dark place. UV-Vis Spectrophotometer (UV-1280, Shimadzu, Japan) was used to calculate the absorbance of the combination at 517 nm. Absorption of a blank sample containing the same amount of methanol and DPPH solution acted as the control while methanol acted as blank sample. Free radical scavenging activity of the crude extracts was calculated by using Eq(3).

$$\text{DPPH}\ (\%) = \frac{\text{A0}-\text{A1}}{\text{A0}} \text{x} 100 \tag{3}$$

where A_0 is the absorbance of the control and A_1 is the absorbance of the sample. Ascorbic acid was used as a positive control. Samples were analysed in triplicate.

3. Results and discussion

3.1 Physicochemical properties of encapsulated EBN

Table 2 shows the results for the physicochemical properties of encapsulated EBNH using microwave drying which includes the colour analysis (C and H° values), moisture content (MC) (%), dissolution (s), solubility (%) and antioxidant activity (%). It shows that all samples were in the desired moisture content range (4 to 13 %) and high solubility (> 85 %). Some samples also show high percentage of DPPH where the highest was 50 %.

Table 2: Responses for the encapsulation of EBN using microwave drying

	Factors			Responses					
Run	A	B	C	C*	H°	MC, %	Dissolution, s	Solubility, %	DPPH, %
EBN_1	7.5	500	1	11.94	59.63	12.74	135	86.5	39.35
EBN_2	7.5	750	1	11.60	61.59	3.87	153	86.1	45.82
EBN_3	10.0	750	10	4.39	38.33	11.43	167	92.3	38.98
EBN_4	10.0	625	10	4.05	36.22	11.11	198	91.6	44.70
EBN_5	5.0	500	5.5	6.50	49.96	12.18	52	88.5	38.14
EBN_6	7.5	750	10	6.03	46.72	10.93	115	92.9	37.61
EBN_7	7.5	625	5.5	5.34	44.23	11.51	121	92.0	49.95
EBN_8	7.5	625	5.5	5.47	44.82	12.75	144	91.4	49.36
EBN_9	5.0	500	5.5	6.14	47.92	11.76	20	90.0	36.55
EBN_{10}	5.0	625	10	8.38	55.93	9.12	104	89.0	38.03
EBN_{11}	7.5	750	10	5.75	46.43	10.13	164	90.7	38.77
EBN_{12}	10.0	625	1	10.43	60.11	7.77	222	89.7	42.90
EBN_{13}	10.0	500	5.5	5.73	46.26	12.13	191	89.0	41.42
EBN_{14}	5.0	625	1	9.02	56.47	12.42	60	91.2	39.88
EBN_{15}	7.5	625	5.5	7.29	52.98	11.97	145	89.5	50.53

3.2 Colour analysis

Table 3 shows the ANOVA result for the sample's chroma value, C* and hue angle, H°. Each model has p-values <0.05 indicating the model is significant. Based on this result, C/W ratio has the most impact on the colour analysis. Based on the experiment done, it indicates that as amount of maltodextrin added decreased, the values of C* and H° of the EBN powder increased. The chroma indicated that the intensity of the samples was not very high, which was most likely related to the crystallize look of the powder. The lower chroma that was recorded shows that the powder has lower colour intensity. Due to the fact that EBNH powder may be used as a functional component without adding any colour to the product, it is extremely advantageous to the food processing industry. Colour measurement is an important quality indicator since it reflects sensory attractiveness and quality of the powders produced during the microwave drying process (Mohd Nawi et al., 2015).

Table 3: ANOVA result for colour analysis

Factor	SS	MS	p-value	
Model (C*)	84.23	9.36	0.0089	Significant
Model (H°)	724.27	120.71	0.0046	Significant
C – C/W ratio (C*)	15.81	15.81	0.0081	
C – C/W ratio (H°)	356.4	356.4	0.0012	

3.3 Moisture content

Table 4 shows the ANOVA result for the EBNH moisture content. The model for EBNH moisture content has p-values <0.05, indicating it was significant. According to the result, time and power had the greatest impact on moisture content. The moisture content of EBNH powder decreased with time and power. The longer drying time and higher power helps to reduce the water content in the sample. For manufacturing processors and testing laboratories, the capability to establish and maintain the right moisture content of a material is important. A food product's properties can suffer if its moisture content is off from the ideal range in a negative way. The targeted moisture content was 5-12 % (dry basis) to ensure that EBNH powder could retain its flavour and nutrition (Geankoplis, 2003). Higher power means higher temperature which will decreased moisture content in the sample. This is due to heat transfer is faster at higher temperatures, lead to more moisture evaporated, resulting in dryer powders (Mishra et al., 2014).

Table 4: ANOVA result for EBN moisture content

Factor	SS	MS	p-value	
Model	76.42	8.49	0.0006	Significant
A - Time	2.06	2.06	0.0336	
B - Power	2.38	2.38	0.0264	

3.4 Dissolution test

Table 5 shows the ANOVA result for the dissolution test. This model has p-values <0.05 indicating the model was significant. The result shows that the dissolution depends mainly on the time of encapsulating the sample in the microwave. As the time of drying increase, the dissolution time also increase. Due to greater swelling brought on by the higher temperature used during microwave drying, larger particles are produced. This resulted in smaller surface area of the powder which may result in increasing the dissolving time (Khadka et al., 2014). The dissolving test helps prevent the release of products that do not perform properly within the intended range. Dissolving a powder is crucial to its bioavailability and medicinal effectiveness.

Table 5: ANOVA result for dissolution test

Factor	SS	MS	p-value	
Model	37569.74	12523.25	< 0.0001	Significant
A - Time	32403.52	32403.52	< 0.0001	

3.5 Solubility

Table 6 shows an ANOVA result for EBNH powder solubility. Model with p-values <0.05 was significant. C/W ratio has the greatest impact on powder solubility. The choice of wall material affects both solubility and the crystalline state of the dried powders. The result shows that the solubility of EBN powder increased with the C/W ratio. Previous study by Mohd Nawi et al. (2015) had reported that maltodextrin showed the lowest dissolution time compared to gum arabic, which means that maltodextrin is highly soluble in water.

Table 6: ANOVA result for EBN powder solubility

Factor	SS	MS	p-value	
Model	40.47	13.49	0.0029	Significant
C – C/W ratio	17.13	17.13	0.0066	

3.6 Antioxidant analysis: DPPH assay

Table 7 shows the ANOVA result for the DPPH assay of the EBN powder. P-values <0.05 indicated that this model for DPPH assay was significant. According to the data, time has the greatest impact on antioxidants. This means that the antioxidant value of EBN powder increases with time. The EBNH powder obtained had high DPPH activity, thus possessed stronger antioxidant effects. Previous study by Ahmad et al. (2020) indicated that interaction between time and C/W ratio affected the antioxidant of black mulberry extract. The significant antioxidant properties of EBNH were closely associated to its functional effects, which include skin rejuvenation, anti-aging (Yida et al., 2015), and a decrease in oxidative stress-related disorders including heart disease (Hou et al., 2015). EBNH may be a natural antioxidant source, which is essential for the food industry seeking alternatives to synthetic antioxidants.

Table 7: ANOVA result for DPPH assay of EBN powder

Factor	SS	MS	p-value	
Model	320.56	35.62	0.0004	Significant
A - Time	42.45	42.45	0.0010	

3.7 Optimisation

The desirable conditions for the encapsulation of EBNH using microwave were determined using Design Expert 13 software. Each analysis was either maximised or minimised. It maximised solubility and DPPH assay and minimised dissolution time, hue degree, chroma value, and moisture content. Optimised condition for microwave drying factor using Design Expert 13 Software was obtained at 9 min, 575 W power and 1:10 C/W ratio (w/w). An experiment and analysis were done based on the optimise conditions obtained for each analysis. Table 8 shows the actual value, predicted value and error for each analysis. After the experiment and analysis, there was no noticeable difference between the predicted and experimental values (error less than 5 %), demonstrating that the designed models were suitable for describing the relation between factors and responses. The results of the study show that the predicted values proposed by the model were acceptable.

Table 8: Optimised value of each analysis

Analysis	Predicted Value	Actual Value	Error, %
H°	40.76 ± 3.85	40.70 ± 3.85	0.16
C	5.28 ± 0.93	5.06 ± 0.93	4.05
Solubility, %	90.00 ± 1.24	92.47 ± 1.24	2.56
Dissolution Time, s	129 ± 25	126 ± 25	2.67
Moisture Content, %	10.83 ± 0.49	10.59 ± 0.49	2.28
Antioxidants: DPPH Assay, %	49.81 ± 0.95	48.83 ± 0.95	1.98

3.8 Model verification

A model verification analysis was carried out in order to ensure that the models obtained were satisfactory (Table 9). The experimental value of each element acted as the control in an experiment. As a result of the experiment and analysis conducted, there was no significant difference statistically between the predicted and experimental values (error less than 5 %), which lead to the conclusion that the developed models were suitable for describing the relationship between factors and responses. The outcome demonstrates that the optimal condition suggested by the model was acceptable.

Table 9: Model verification of each analysis

Analysis	Optimise Value	Experimental Value	Error, %
H°	40.69 ± 3.85	40.96 ± 3.85	0.64
C	5.06 ± 0.93	5.30 ± 0.93	4.53
Solubility, %	92.47 ± 1.24	90.18 ± 1.24	2.54
Dissolution Time, s	126 ± 25	130 ± 25	3.08
Moisture Content, %	10.59 ± 0.49	10.89 ± 0.49	2.79
Antioxidants: DPPH Assay, %	48.83 ± 0.95	47.76 ± 0.95	2.22

4. Conclusion

The optimised condition for EBNH encapsulation using microwave drying was obtained at 9 min, 575 W power and 1:10 C/W ratio (w/w). It was discovered that the C/W ratio had a substantial impact on the hue angle, chroma value, and solubility of the powder in the final product. It was observed that the drying time in the microwave had a positive effect on the dissolving time, antioxidant and the moisture content of the encapsulated EBNH. It was shown that microwave power had an effect on moisture content. Microwave-assisted encapsulation technology is environmentally friendly and reduces the processing time in food production. It has the ability to produce an encapsulated EBNH product with a high lightness value, high solubility, and high antioxidant activity which is highly beneficial for food industry.

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