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RESEARCH ARTICLE

DRYING, COLOUR AND SENSORY CHARACTERISTICS OF 'BERANGAN' BANANA (MUSA ACCUMINATA) FLESH DRIED USING A MICROWAVE OVEN

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ABSTRACT

The drying characteristics of 'Berangan' banana flesh dried under microwave heating were studied in this work. The produced microwave banana chip was then compared with the conventional deep oil fried banana chip in terms of colour and sensory characteristics.'Berangan' banana slices with 3 mm thickness were dried using microwave at three power levels of 100, 440 and 1000 W. Shorter drying times were obtained when higher microwave power was applied during drying, where the drying times were found to be 30, 7, 4 min at 100, 440 and 100W. Three different drying models were used to describe the resulting drying curves. The drying rate constant increased from 0.298, 0.4211 and 0.2977 min^{-1} to 1.8717, 1.9956 and 1.8936 min^{-1} for the Newton, Page and Henderson and Pabis models when the microwave power used was increased from 100W to 1000W. The best model to represent the drying data obtained in this work was found to be the Page model. In terms of colour, fried banana had a browner, duller colour than microwave dried banana. For sensory evaluation, dried banana chips using microwave at a power level of 440W was the most preferable. It can be concluded microwave dried banana chips showed better results than fried banana chips in terms of colour and sensory characteristics in the range tested in this study.

KEYWORDS

Berangan banana, banana chips, microwave drying, colour, sensory.

1. INTRODUCTION

Banana (*Musa acuminata*) is a low cost of agricultural product with high sugar content and nutritional value [1]. However, the quality of bananas deteriorates rapidly after harvesting [2]. Therefore, the drying process is introduced to preserve the banana by reducing its moisture content. This dehydration method creates a number of products derived from banana and thus increases the value of fresh banana [3]. Various value-added dried banana products with extended shelf life are developed to minimize the problem of oversupply of banana during harvesting season.

Banana chips, consumed as snacks, are one of the products that can be obtained from raw banana. The demand of healthy snack food in the world shows an increase trend [4]. Banana chips have nutritional benefits due to its high fiber content, iron and potassium. Therefore, there is market potential for the banana chip industry in Malaysia because there is a growing consumer concern towards halal and healthy food. Banana chips are normally produced by frying thin-sliced bananas with vegetable oil [3]. Fried banana chips are crispy and highly delicious due to the formation of crusts [1]. However, fried banana chips contain high fat content, which will shorten the shelf life of the product caused by rancidity [3]. Therefore, microwave drying is introduced to produce crispy banana chips.

Microwave heating is utilized to dehydrate the moisture from food products in the food industry. The entire food products are heated up quickly from inside to outside by microwave penetrate deeply into the food product [5]. Hence, the water is evaporated as vapor rapidly, which results in reduction in drying time [6]. Their studies showed that the drying time was reduced 70-90% for mushroom using microwave vacuum drying. The shorter microwave drying time is improving the product quality.

In addition, microwave heating consumes relatively lower energy because of this relatively short drying time [7]. Dried products by microwave heating is also healthier compared to fried products in terms of fat content. Some researchers found a reduction of at least 90% of the fat content of the durian chips was obtained compared with durian chips produced using the conventional deep frying [5]. Lower fat content in the food products will extend the shelf life of the product and beneficial to human health.

It was also found that dried product bulk density and rehydration would be reduced in addition to the increase in the dried product toughness and shrinkage occurring thus compromising the overall dried product quality when the drying time was prolonged [8]. Therefore, the drying rate of banana using microwave heating is very important to be considered. Besides that, different power levels of microwave will also influence the drying rate of the banana. Dried banana chips can have different physical characteristics in terms of crispness and colour depending on different drying method. The dried product physical characteristics are very important since they affect the acceptability of customer towards the product. Previous works that utilized microwave for drying purposes have also reported relatively shorter drying times compared to conventional drying methods such as oven for the drying of nepheliumlappaceum (rambutan) seeds [9, 10]. Furthermore, some important sensorial characteristics of foods were better preserved when using microwave compared to conventional cooking such as those for beef [11]. Recently, advanced microwave drying equipments involving vacuumed and flashed conditions were used to dry banana slices and relatively good sensory characteristics such as crispness were obtained [12]. Apart from sensory characteristics, the quality of the material dried under microwave drying such as its antioxidant properties was better preserved compared when drying under conventional oven drying for the case of coconut husk [13]. Hence, in this current study, microwave drying is presented as a process to produce banana chips from banana flesh. The microwave drying characteristics of the banana flesh were examined in terms of drying curves and the application of established drying models. In addition, the important characteristics of the produced banana chips via microwave drying of banana flesh consisting of their colour and sensory characteristics have also been studied in this work These were then compared with banana chips prepared via the conventional deep frying method so that comparisons could be made in terms of the colour and sensory characteristics, which are generally regarded as important characterisctics by the consumers. Therefore, this current work will be useful to aid the use of microwave for the production of banana chips especially for domestic and small-scale industrial use.

2. MATERIAL AND METHODOLOGY

2.1 Material preparation

'Berangan' bananas were purchased from the local market. These bananas were then hand peeled. 3mm thickness of banana slices were made using a two fixed blades cutter. The fruit ends were rejected because the diameters were smaller.

2.2 Microwave drying

Banana slice was dried at three different level of microwave power 100W (low level), 440W (medium level) and 1000W (high level) using a microwave oven model NN-C2003S (Panasonic, Malaysia). The weight loss of the banana slice was measured every 5 minutes, 1 minute and 20 seconds intervals for low, medium and high-power levels respectively using an analytical balance model AY220 (Shimadzu, Japan). Drying process was continued until the weight was constant. The measurements were repeated three times.

2.2.1 Drying profile

The drying profile used in this study was the drying curve. Free moisture content, X, (Eq. (1)) referred to the water loss at a particular time, termed as the free moisture content (X), is given by:

$$X = X_t - X^* \qquad (1)$$

where X_t was the moisture content at time (t) was calculated using (Eq.(2)) and X^* was equilibrium moisture content (kg equilibrium moisture kg dry solid^{-1}):

$$X_t = \frac{W - W_s}{W_s} \qquad (2)$$

where W is weight of the wet solid in (kg) and W_s is weight of dry solid in (kg).

2.2.2 Thin layer drying model

The models used in order to evaluate the drying characteristics of the banana flesh are listed in Table 1. The application of these drying models to the experimental data would then yield the k values, which is the drying rate. Meanwhile, the values of n and a were constant values obtained through the fitting of the models to the experimental data. Through the assumption of relatively small values of M_e in comparison to both M and M_0 values, the moisture ratio could then be approximated to M/M_0 from the original $(M - M_e)/(M_0 - M_e)$.

Table 1: Drying models used in this work [14].

No.	Model name	Model
1	Newton	$MR = \exp(-kt)$
2	Page	$MR = \exp(-kt^n)$
3	Henderson and Pabis	$MR = a.\exp(-kt)$

The values of the correlation coefficient (R^2) as well as the root mean square error (*RMSE*) were used to determine the model that best fit the data obtained in this work. The best fitted model would exhibit a relatively high R^2 value and low RMSE value.

2.3 Deep-fat frying

For comparison purposes, deep fat frying for the banana flesh was performed in a deep fryer model FDF 1002 (Faber, Italy). The unit was filled with Daisy corn oil, made from pure corn oil. The oil temperature used for frying the samples was at 180 °C. The time duration for frying was between 45 and 120 s [15].

2.4 Dried banana flesh colour and sensorial characteristics

2.4.1 Colour

A color spectrophotometer (model Ultra Scan PRO, Hunter Lab, United States) was utilized to measure the colour of the banana chips. The color was measured from samples of microwave drying and deep-fat frying. The lightness (L*), redness (a*) and yellowness(b*) scales were used to report the colour of the banana chips.

2.4.2 Sensory evaluation

Forty students at the University Putra Malaysia (UPM) were appointed as untrained panelist in this sensory evaluation study. They were asked to evaluate 4 samples: microwave dried banana chips (3 samples at 3 different power levels) and the conventional deep-fat fried banana chips in terms of overall acceptability, appearance, aroma and crispness based on a 9-point hedonic scale [15]. (Scale 1 = dislike extremely, 2 = dislike very much, 3 = dislike moderately, 4 = dislike slightly, 5 = neither like or dislike, 6 = like slightly, 7 = like moderately, 8 = like very much, 9 = like extremely). In order to determine the significance differences in this sensory evaluation study, statistical analysis involving the analysis of variance (ANOVA) and followed by Tukey's test were utilized.

3. RESULT AND DISCUSSION

3.1 Drying characteristics

3.1.1 Drying profile

Figure 1 shows the drying curve for banana flesh under microwave drying, at different microwave power levels (100W, 440W, 1000W). It can be observed that the moisture decreased exponentially when the drying time increased at all microwave power levels. The time required to dry the banana samples until a constant weight was found to be 30, 7, 4 min at 100, 440 and 100W, respectively. The highest power level of 1000W consumed the shortest drying time, which was 4 min. Shorter drying times at higher power levels gave indication of a quick moisture removal. Hence, the results indicated rapid moisture removal within the sample with the increased in the microwave power level used. This is due to microwave volumetric heating caused by therelatively higher amount of heat generated within the sample. A relatively large vapor pressure difference would then occur between the internal and the surface of the sample [16]. This is in line with other previous studies, such as for durian, apple, sorbus fruit and mushroom [5,6,16,17]. Previous works also reported that the decrease in drying time with the increase in the microwave power used generally would better preserve the quality of food products as for the case of antioxidant activity in coriander leaves [18]. This was also observed for the case of coffee beans dried under microwave vacuum process, where relatively higher total phenolics contents as well as increasing antioxidant activity were observed at higher microwave power used in the process [19].

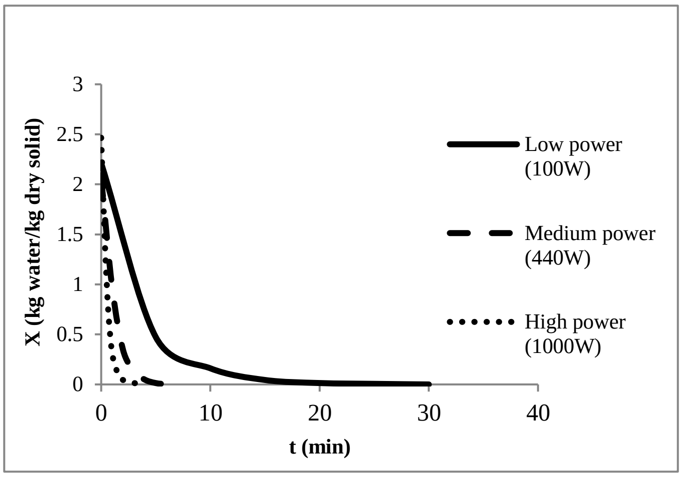

Figure 1: Drying curve for banana flesh at varying power levels (100W, 440W, 1000W).

3.1.2 Mathematical Modeling

Table 2 shows the values of constants of the thin layer drying models. From the results, larger values of the drying rate, k were obtained when the microwave power was increased. This can be observed in Newton, Page and Henderson and Pabis models. The drying rate constant increased from 0.298, 0.4211 and 0.2977 min^{-1} to 1.8717, 1.9956 and 1.8936 min^{-1} in Newton, Page and Henderson and Pabis models respectively with increasing microwave power. Similar observations were reported for apple slices and rambutan seed [9-11].

In general, all the fitted models gave values of R^2 higher than 0.90, therefore the models describe the experimental data well. Page model was concluded to be the best model based on its highest values of R^2 and lowest values of $RMSE$. As it was seen, the R^2 and $RMSE$ values for Page model ranged from 0.9910 to 0.9965 and 0.0028 to 0.0055, respectively. A similar result was also obtained in a recent work involving the microwave drying of rambutan seed [10].

Table 2: Values of parameters for respective models at different microwave power levels.

Power (W)	Models	Constant parameters			R^2	$RMSE$
		k (min^{-1})	n	a		
100	Newton	0.2980			0.9941	0.0109
	Page	0.4211	0.8046		0.9910	0.0028
	Henderson and Pabis	0.2977		0.9986	0.9941	0.0109
440	Newton	0.8304			0.9855	0.0190
	Page	0.7546	1.2080		0.9937	0.0043
	Henderson and Pabis	0.8362		1.0092	0.9855	0.0187
1000	Newton	1.8717			0.9879	0.0218
	Page	1.9956	1.1613		0.9965	0.0055
	Henderson and Pabis	1.8936		1.0139	0.9879	0.0149

3.2 Banana chip colour

Table 3 showed the results of colour measurement of dried banana samples with different drying treatments. The L*colour parameter indicated whiteness of the sample; a*colour parameter indicated the redness of the product and b*colour parameter measured the yellowness of the product. For dried banana, preferred colours were light or golden colour. Based on the results, fried banana sample showed the lowest value of L*, a* and b* which could be due to the higher temperature of frying and longer frying time causing browning of banana crisp. Fried banana was darker and had a browner, duller colour than the microwave dried banana. Microwave drying at 100W consumed longer time of drying, but its L* values showed the highest because the banana was dried at low power level. Banana dried with microwave power level at 1000W showed results of highest value of a*, presenting redder colour of banana. It can be concluded that microwave dried banana showed the highest value of L*, a* and b* if compared to fried banana chip. The real picture of banana chips with different drying treatments were shown in Figures 2, 3, 4 and 5.

Table 3: Colour values of banana flesh at varying power and drying treatment.

Drying treatment	L*	a*	b*
Microwave drying (100W)	31.04±1.57	9.48±1.09	15.74±0.60
Microwave drying (440W)	23.52±0.37	9.64±0.97	13.16±1.35
Microwave drying (1000W)	27.63±0.45	10.85±0.42	19.78±1.79
Frying	15.61±0.81	4.50±0.84	10.09±0.38

Figure 2: Top view of microwave dried banana at 100W.

Figure 3: Top view of microwave dried banana at 440W.

Figure 4: Top view of microwave dried banana at 1000W.

Figure 5: Top view of fried banana.

3.3 Sensory characteristics

Sensory evaluation of the dried banana chips were shown in Figure 6. It can be seen that microwave dried banana chips had a significantly higher score in terms of crispness, appearance, aroma and overall acceptability than fried banana chips. However, dried banana crisp at power level of 440W had higher scores of overall acceptability than those from the frying method, but the scores of crispness were lower than another two power levels. This can be seen that the reason for overall acceptability was not due to the crispness of banana chips. Microwave dried banana crisps at 440W had the highest scores in terms of aroma and appearance. The results of the current study indicated that microwave dried banana chips would be more preferable over the fried banana chips within consumers.
There was a statistically significant difference between samples as determined by one-way ANOVA for sensory attributes of crispness, appearance and overall acceptance ($p \leq 0.05$). For sensory attributes of aroma, the four samples were not significantly different ($p > 0.05$). A Tukey post hoc test showed that the samples A-D, B-C, B-D and C-D were significantly different in terms of crispness. Samples A-B and A-C sensory attribute of crispness was not significantly different between them. The appearance of the samples was significantly different between the samples A-D, B-D and C-D. Meanwhile, samples A-B, A-C and B-C were not significantly different. In terms of overall acceptance, the results indicated that the samples A-D, B-D and C-D were significantly different. The samples A-B, A-C and B-C were not significantly different.

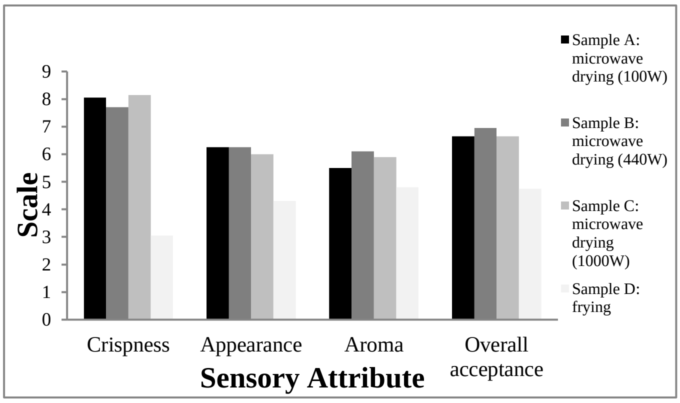

Figure 6: Sensory evaluation of dried banana chips.

4. CONCLUSION

The increase in the microwave power used would decrease the drying time hence increasing the drying rate. The highest drying rate was obtained at the highest microwave power of 1000W. The data obtained in this work was best fitted with the Page model. In terms of colour, fried banana had a browner, duller colour than microwave dried banana with lowest value of L^*, a^* and b^* values. For the sensory evaluation test, microwave dried banana crisp at 440W was the most preferable amongst the panelists. It can be concluded that microwave dried banana chips showed better results than fried banana chips in terms of colour and sensory characteristics in the range tested in this study.

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