



Effect of Pre-treatment in Producing Pumpkin Powder Using Air Fryer and Its Application in 'Bingka' Baking

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Abstract

Pumpkin powder has longer shelf life and acts as a substitute for pumpkin flesh in different types of formulated foods. This work focused on producing pumpkin powder from different pumpkin parts and evaluating the effects of powder substitution on the physical properties of cake (bingka). Different parts of pumpkin (peeled, unpeeled, and skin) were pre-treated by soaking in limewater solution and then dried in an air fryer at 80°C, 120 min and air flow of 5.11 m/s. The fresh pumpkin (peeled and unpeeled) and pumpkin powder (from peeled and unpeeled pumpkin) were both used in the production of 'bingka' and the baking parameters were optimised. The selected temperatures for baking were in the range of 130–150°C and the baking time was between 25 and 35 min. Baking temperature and time had a significant effect ($p < 0.05$) on moisture content and hardness, but are insignificant towards chewiness. The 'bingka' made from peeled pumpkin and baked at optimum baking temperature (130°C) and time (25 min) had higher moisture content (45.92%) as compared to those made using unpeeled pumpkin 43.47%, peeled pumpkin powder (44.23%) and unpeeled pumpkin powder (43.47%). Pumpkin powder is a great substitute for the raw pumpkin used in food. The quality of the produced food are comparable to the ones produced using raw pumpkin.



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Powder;
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Introduction


Pumpkin (*Cucurbita maxima*) is one of the vegetables that is high in nutrition and can be used as food, as

well as in medicines. Pumpkins are soft and sweet. They are used in a variety of food products such as cakes (Anju, 2013), breads (Pongjanta *et al.*,

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2006), cookies (Kulkarni & Joshi, 2013), Asian noodles (Lee *et al.*, 2002), rice breads (Dabash *et al.*, 2017), jellies (Yoshimura *et al.*, 1994), sauces (Sosa *et al.*, 2013), and marmalades (Egbekun *et al.*, 1998). Different parts of pumpkins have different nutrient contents. Pumpkin skin is a good source of pectin but it is normally discarded as agricultural waste during processing. There is insufficient information and research available on the utilization of pumpkin skin.

Pumpkins are very sensitive; even if they are stored in a refrigerator, they are prone to microbial spoilage (Anju, 2013). In fact, they deteriorate a few weeks after harvesting due to their high moisture content, which is about 92% (Tunde-Akintunde & Ogunlakin, 2011). Thus, it is difficult to retain the nutrients, taste, and colour of pumpkins.

Soaking in the calcium solution might give better quality to the final product, such as prevention in microbiological growth, improvement in texture, and maintain in color, (Alandes *et al.*, 2009). However, certain solution may have adverse effect on the product, due to presence of SO₂ subscript allergenic effect to the consumers (Aydin and Gocmen, 2015). Calcium hydroxide is commonly used for food production. Therefore, it may be used as an alternative to preserve the food quality in order to maintain the color and extend the shelf life. These characteristics are beneficial to develop food which is rich in calcium, such as high calcium milk, high calcium bread, flour, and others (Lee *et al.*, 2002).

Drying is the perfect method for their preservation and this is achieved by hot air drying (Aydin & Gocmen, 2015), air frying (Murzaini *et al.*, 2016), and freeze-drying (Que *et al.*, 2008). Currently, pumpkin flour is the main processed product of pumpkins, which can be easily stored for a long time and is used in the manufacturing of formulated foods (Aydin & Gocmen, 2015).

'Bingka' is a traditional dessert that is popular in the Malay society. Conventionally, 'bingka' is made from coconut milk, eggs, sugar, and butter. In the production of 'bingka', sugar is the most important ingredient because it affects starch gelatinisation, texture, sweetness, and colour of the product

(Gan *et al.*, 2007). The sensory characteristics of baked 'bingka' are creamy, sweet, and full of pumpkin flavour.

Air frying is a new baking technique that involves rapid air circulation. An air fryer is designed to dry and bake. Hot air is rapidly circulated in order to maintain a uniform temperature. The cooking chamber of an air fryer receives heat from the heating element close to the sample, hence the duration of cooking is shortened (Rahman *et al.*, 2017). The presence of air flow modulates the temperature by distributing the hot air inside the chamber; this enhances the baking process and reduces baking time. A lower baking temperature in the presence of air flow is more efficient in terms of working time (Sani *et al.*, 2014).

Response surface methodology (RSM) is a collection of mathematical and statistical techniques that utilise quantitative data from experimental designs for solving multivariate problems, in which several independent variables influence a dependent response (Jang *et al.*, 2011). This method is an effective tool in the development of experiments and has officially been used to optimise several food processing operations (Rahman *et al.*, 2017). Many researchers have conducted optimisation studies using RSM to calculate the data. Examples of such studies include the optimisation of steamed foam cakes prepared via separated-egg-sponge method (Jang *et al.*, 2011), the selection of ingredients and baking process for improving the quality of wholemeal oat breads (Flander *et al.*, 2007), rice cake-baking in infrared-microwave combination ovens (Turabi *et al.*, 2008), the basic formulation of a traditionally-baked cassava cake (Gan *et al.*, 2007), the formulation of soy cakes baked in infrared-microwave combination ovens (Şakıyan, 2015), as well as processing conditions and formulations of microwave-baked rice cakes (Alifakı *et al.*, 2016).

In food processing, moisture content and texture properties such as hardness and chewiness are important criteria to determine the quality of food products. Therefore, this research aims to evaluate the physicochemical properties of pumpkin powder and to optimise the temperature and time on the physical properties of 'bingka'.

Materials and Methods

Materials Preparation

The samples were divided into three groups i.e. peeled pumpkin, unpeeled pumpkin and pumpkin skin. All of the samples were then further categorized into treated and untreated samples. Treated samples were soaked in limewater as a pretreatment process. The untreated sample without pre-treatment process was used as the control samples. Both treated and untreated samples were dried in the same condition of temperature and time.

Cutting Process

Pumpkins were purchased from a local market. Pumpkins were selected based on based on their size, which was about 1 kg per pumpkin. Pumpkins were purchased from a local market. Firstly, the pumpkins were washed to make sure that dirt and foreign material on the pumpkin skin were removed. The peeled and unpeeled were sliced (2 cm x 1 cm x 0.1 cm) and the skin was cut into the rectangular shape (2.0 cm x 1.0 cm).

Pre-Treatment Process

Pre-treatment was conducted on the pumpkin samples before drying process, which is known as calcium impregnation. The samples were soaked in a limewater solution (1:7, v/v, 1 part of Ca(OH)₂ and 7 parts of water at the standard concentration of 0.02 mg/mL for 25 min at room temperature (Keen *et al.*, 2016). Then, the samples were washed with tap water before being dried with an absorbent paper.

Drying Process

The peeled pumpkin, unpeeled pumpkin, and pumpkin skin samples were dried using a commercial hot air fryer (Philips, HD9220/20, United Kingdom) with effective air velocity of approximately 5.12 m/s. The drying time and temperature for the air fryer can be controlled based on the desired process conditions. The conditions of drying parameters for temperature and time are 80°C and 120 min, respectively.

After drying, the samples were allowed to cool down at room temperature. Then, the pumpkin samples were ground using an electronic blender and subsequently sieved using a standard steel sieve shaker (Minor Sieve Shaker, Endecott, London, England) through the size of 250 μm (60 mesh) to

produce peeled pumpkin, unpeeled pumpkin, and pumpkin skin powder (Aukkanit and Sirichokworrakit, 2017). The powder was kept in a sealed plastic bag at room temperature for further investigation.

Analysis of Dried Pumpkin Powder

After drying process, the dried pumpkin powder was followed by analysis process (moisture content, water activity, colour, particle size and particles morphology).

Moisture Content Analysis

The moisture content of pumpkin powder was analysed using a moisture analyser (Infrared moisture balance, MX-50 A & D Weighing, Adelaide, Australia) under a standard drying programme (accuracy = 0.05% min⁻¹). The results obtained using this instrument were validated by the standard air oven method for total solids and baked products after overnight drying at 105°C (AOAC, 2005).

Water Activity Analysis

A water activity meter (GDH Instrumentation Scientifique, France) was used to measure the water activity of the powder. Three triplicates measurements of water activity were performed for each sample (AOAC, 2005).

Colour Analysis

An Ultrascan PRO spectrophotometer (A60-1012-402 Model Colorimeter, Hunter Lab, Reston, VA, USA) was used to measure the colour intensities of peeled pumpkin, unpeeled pumpkin, and pumpkin skin powder. The parameters monitored were L^* (whiteness/darkness), a^* (redness/greenness), b^* (blueness/yellowness) values and L_0^* , a_0^* , b_0^* (colour coefficients) for raw pumpkin (Pathare *et al.*, 2013). The measurements were performed in triplicate. Total colour difference (ΔE) was calculated as follows in eq.1: ΔE - relative colour difference index:

$$\Delta E = \sqrt{(L_0^* - L^*)^2 + (a_0^* - a^*)^2 + (b_0^* - b^*)^2} \quad \dots(1)$$

Particle Size Analysis

The size of powder particles was determined by using a laser light diffraction instrument, Mastersizer 2000 (Malvern Instruments, Malvern, U.K) (Tze *et al.*, 2012). The particle size was determined as the mean diameter over the volume distribution,

which is usually used to characterise a particle and was expressed as D[4,3] (Tonon *et al.*, 2008). The particle size was measured in triplicates for treated and untreated pumpkin samples.

Particles Morphology Analysis

Particles morphology was evaluated by scanning electron microscopy (SEM) (Hitachi, S-3400N, Tokyo, Japan) (Tonon *et al.*, 2008). A 10-mm sample was mounted on a gold stub and sputter-coated (EMITECH, K550X, Quorum Technologies Ltd, East Sussex, UK) with platinum prior to the morphological assessment. The voltage used was 5 kV throughout the scanning process.

Preparations of Baking Pumpkin 'Bingka'.

This stage of this study was to apply the powder produced were then used for 'bingka' baking.

Preparation of 'bingka'

All the ingredients above were weighed using an electronic balance and placed into containers separately. The formulation of 'bingka' made of fresh pumpkin consists of 34.1% boiled and mashed pumpkin, 18.7% flour, 14.1% egg, 10.7% coconut milk, 11.8% sugar, 0.5% margarine, 9.6% condensed milk, 0.3% salt and 0.2% vanilla essence. The formulation of 'bingka' recipe that used powdered pumpkin samples is about 8.6% pumpkin powder, 25.5% plain water, 18.7% flour, 14.1% egg, 10.7% coconut milk, 11.8% sugar, 0.5% buttercup, 9.6% condensed milk, 0.3% salt and 0.2% vanilla essence.

Before baking, the initial moisture content of the batter were standardised to the value of $48.75 \pm 0.12\%$ (wet basis). Then the batter was poured into a round baking pan. Then, the pumpkin 'bingka' were baked by using air fryer.

Baking Process

Baking was done in a 1vvg.425-Watt air fryer (Philips, HD9220, United Kingdom) with air velocity of 5.11 m/s. The baking conditions were obtained from previous preliminary experiments at 130, 140, and 150°C for 25, 30, and 35 min, respectively. For each condition, a convention oven was used for baking the control sample. The speed of air velocity in the convection oven was 0.08 m/s.

Optimisation of Baking Parameters

Moisture Content Analysis

Three slices of cakes measuring 2.5 cm³ each were cut and their moisture content was analysed using a moisture analyser as mentioned in Section 2.2.1.

Texture Analysis

Texture analysis of the 'bingka' (made from peeled and unpeeled pumpkin) was performed using a texture analyser (Model TA-XT2i, Stable Micro Systems, England). Three slices of cakes measuring 2.5 cm³ each were cut as shown in Figure 4. For the textural test (hardness and chewiness), a 35-mm cylinder (P/35) probe was selected for the texture analyser (Changern and Suriyaphan, 2009). For the consistency of the measurements, the average of triplicate determinations were obtained.

Optimisation of Baking Process Using Response Surface Methodology

A rotatable central composite design (CCD) was used to design the tests for the optimisation of baking process, which were temperature and time for baking pumpkin 'bingka'. The measured responses were moisture content, hardness, and chewiness. According to the CCD, 13 experimental runs were performed, and the centre point determination was repeated six times. RSM was used to analyse the experimental data in the optimisation process (Patil *et al.*, 2014). RSM using Design-Expert software version 10.0.3.1 (Stat Ease Inc., Minneapolis, USA) was used with 2-variable, 3-level CCD. A composite function with a quadratic model was devised to study the combined effects of two independent variables of baking temperature and baking time.

Verification of Data

The optimum processing temperature and time were obtained by superimposing the plots for all the response variables. The selection of the optimum parameters used for analysing the predicted values of response variables was based on the predictive equation derived by RSM (Gan *et al.*, 2007). The verification of the optimal formulations for making baked pumpkin cakes was performed. The processing parameters in the presence of optimum temperature and time were analysed, and the results were compared with the predicted values.

Results and Discussion

Effect of Pre-Treatment on Moisture Content and Water Activity

Based on Table 1, the moisture content and water activity of peeled pumpkin powder have the lowest values (non-treated = 5.68 ± 0.23 and treated = 5.18 ± 0.15 ; untreated = 0.341 ± 0.03 and

treated = 0.319 ± 0.05) respectively, compared to unpeeled pumpkin and pumpkin skin powder. The result shows that treated peeled pumpkin, unpeeled pumpkin, and pumpkin skin had a lower moisture content and water activity compared to non-treated samples of pumpkin powder.

Table 1: The moisture content and water activity of untreated and treated pumpkin powder

Samples	Moisture Content (%)		Water Activity	
	Untreated	Treated	Untreated	Treated
Peeled	5.68 ± 0.23^b	5.18 ± 0.15^a	0.341 ± 0.03^c	0.319 ± 0.05^b
Unpeeled	6.64 ± 0.46^b	6.16 ± 0.39^a	0.359 ± 0.01^c	0.323 ± 0.16^a
Skin	7.07 ± 0.62^b	6.23 ± 2.45^a	0.387 ± 0.01^c	0.342 ± 0.23^a

Superscript (a,b,c,...) = Treatment significant ($p < 0.05$) in order to column.

Values are mean \pm standard error,

This is because the treated sample is subjected to calcium pre-treatment, which reduces the moisture content by approximately 0.06%–0.51% in all parts of pumpkin powder (Keen *et al.*, 2016). This is further explained by the addition of Ca^{2+} that contributes to the stabilisation of membrane systems and forming Ca precipitate. It would also increase the rigidity of the middle lamella and cell wall. Therefore, after the drying process, there is a reduction of moisture content and water activity in pumpkin powder and the structure of the sample becomes more crispy and brittle.

The moisture content and water activity of unpeeled powder are lower (untreated= 6.64 ± 0.46 and treated= 6.16 ± 0.39 ; untreated= 0.359 ± 0.01 and treated= 0.323 ± 0.16), than pumpkin skin powder. The moisture content of pumpkin skin is low (untreated= 7.07 ± 0.62 ; treated= 6.23 ± 2.45) in some parts of pumpkin. The skin texture is bumpy and slightly rough. This finding is supported by (Keen *et al.*, 2016), in which low water activity level of pumpkin powder suggests a better keeping quality as most of the unfavourable changes in food occur during storage. In this work, the water activity below 0.6 for all samples indicates that the samples are microbiologically safe (Quek *et al.*, 2007).

Effect of Pre-Treatment on The Colour of Pumpkin Powder

L^* values represent the degree of lightness. The units are in the form of degrees (or angles), ranging from 0° (red) to 90° (yellow) 180° (green), 270° (blue) and back to 0° (McGuire, 1992). For the limewater-treated powder, the samples have the highest L^* values of 64.10 ± 0.10 (peeled pumpkin), 64.43 ± 0.32 (unpeeled pumpkin), and 62.27 ± 0.23 (pumpkin skin) compared to non-treated samples (60.30 ± 0.30 , 56.0 ± 0.40 , and 60.07 ± 0.40 for peeled pumpkin, unpeeled pumpkin, and pumpkin skin, respectively). Higher L^* values indicate a great browning occurred during heating (Manganaris *et al.*, 2005).

ΔE represents the effect of treated samples on the total changes of different parts of pumpkin powder. The total changes of the treated samples are higher than untreated samples. The values of the treated samples are 14.04 ± 0.76 (peeled), 15.58 ± 2.44 (unpeeled), and 11.85 ± 0.81 (skin) compared to the values of the untreated samples of 8.00 ± 0.02 (peeled), 12.58 ± 0.50 (unpeeled), and 10.13 ± 0.54 (skin). This is due to loss of the Ca^{2+} ions in the fruit cell will occur the browning and calcium treatment will reduce browning by stabilizing the Ca^{2+} ions in

cell membranes (Poovaiah, 1986; Hopfinger *et al.*, 1984). Drying conditions, including high temperature, light, and oxygen exposure, can cause changes

in food surface characteristics that change the colour and may cause carotenoid degradation (Workneh *et al.*, 2012).

Table 2: The colour of peeled pumpkin, unpeeled pumpkin and pumpkin skin powder

Samples		L*	a*	b*	ΔE
Peeled	Untreated	60.30 ± 0.30	11.40 ± 0.17	49.67 ± 0.32	8.00 ± 0.02
	Treated	64.10 ± 0.10	9.87 ± 0.06	53.47 ± 0.31	14.04 ± 0.76
Unpeeled	Untreated	56.70 ± 0.40	12.70 ± 0.20	43.10 ± 0.53	12.58 ± 0.50
	Treated	64.43 ± 0.32	8.50 ± 0.20	49.47 ± 0.21	15.58 ± 2.44
Skin	Untreated	60.07 ± 0.40	6.57 ± 0.21	43.17 ± 0.42	10.13 ± 0.54
	Treated	62.27 ± 0.23	6.50 ± 0.10	43.80 ± 0.26	11.85 ± 0.81

Effect of Pre-Treatment on The Particle Size of Pumpkin Powder

Based on Table 3, the particle size of the treated samples is lower than the untreated samples. This study is reasonable because limewater treatment shrinks pumpkin tissues, which allows osmosis to occur. Osmosis is a process where substance flows from high concentration to low concentration. Previously, calcium treatment from limewater can firm the sample (Keen *et al.*, 2016). After drying process occurs, it will reduce the moisture content in the sample and change the structure of the sample to be more brittle and easy to dry.

The particle size of the treated samples is smaller than the untreated samples. For different parts of pumpkin, the skin has the lowest particle size compared to other parts. The particle size of the skin is 103.03 μm for the untreated samples and 97.96 μm for the treated samples. The moisture content of the skin is higher than peeled and unpeeled skin samples but has the lowest particle size. This is because the texture of pumpkin skin is so unique that the rough texture needs time to dry.

Effect of Pre-Treatment on The Structure of Pumpkin Powder

Figures 1–3 show the images of SEM taken to observe the surface structure of optimised treated and untreated pumpkin powder samples. The surface structures for treated peeled, unpeeled, and skin samples are more clotted than the treated samples. This is due to the removal of free water during drying process and microstructure stresses developed

Table 3: Particle size of untreated and treated pumpkin powder

Samples	Particle Size (μm)	
	Untreated	Treated
Peeled	122.78 ± 0.15 ^a	120.99 ± 2.54 ^b
Unpeeled	139.11 ± 0.72 ^b	112.71 ± 0.31 ^b
Skin	103.03 ± 0.34 ^a	97.96 ± 0.86 ^b

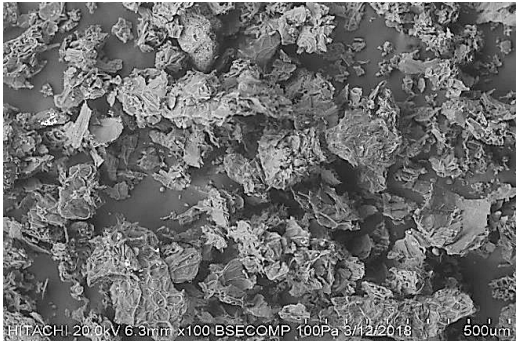
Superscript (a,b,c,...) = Treatment significant ($p < 0.05$) in order to column. Values are mean ± standard error

inside the products (Rahman *et al.*, 2017). The structure for untreated samples of pumpkin powder becomes flakes and the surface area of particle size is bigger than the treated samples. The treated pumpkin powder samples appear to have more open and larger pores in the microstructure probably due to the pre-treatment of samples in limewater.

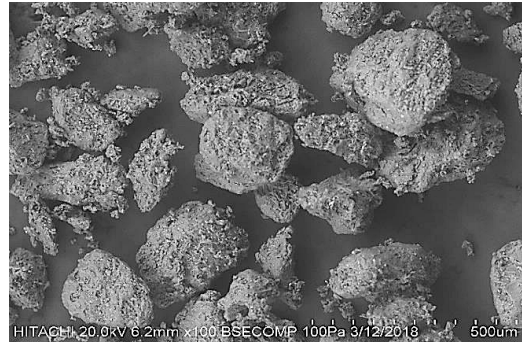
The moisture contents of peeled pumpkin powder are 5.18% for the untreated samples and 5.68% for the untreated samples. Meanwhile, the particle sizes of peeled pumpkin powder are 122.78 μm for the non-treated samples and 120.99 μm for the treated samples. Both criteria have the lowest moisture content and the highest particle size. Based on Figure 1(a), the image taken is similar to a flake but Figure 1(b) appears to be more clotted. Besides, for skin sample, the moisture contents are 7.07% (untreated) and 6.23% (treated). Furthermore, the particle sizes are 103.03 μm (untreated) and

97.06 μm (treated). The skin of the treated samples has higher moisture content and smaller particle size. From Figure 3(b), it can be seen that the particle size in the image is smaller than the particle size in

Figure 3(a). From SEM images, it can be concluded that the image of the treated samples has smaller particle size than the untreated samples.

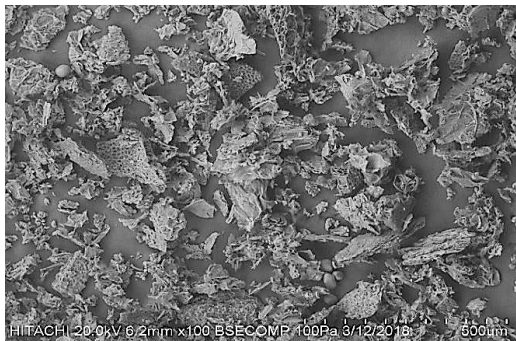


(a)



(b)

Fig. 1: Scanning electron micrographs of peeled pumpkin powder (a) untreated (b) treated

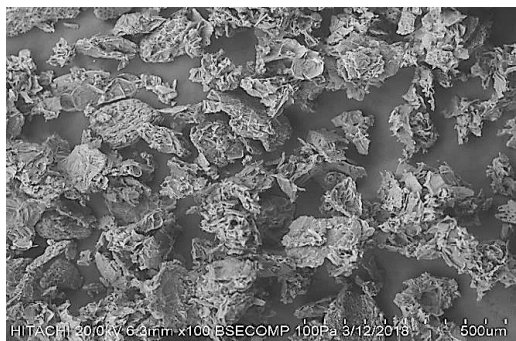


(a)

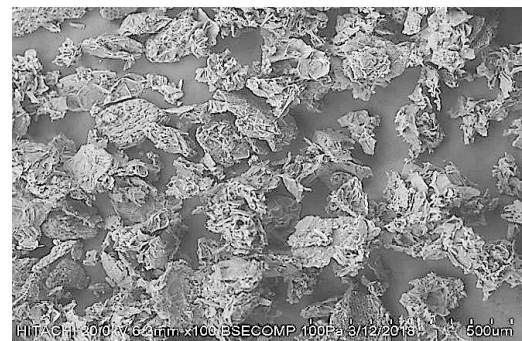


(b)

Fig. 2: Scanning electron micrographs of unpeeled pumpkin powder (a) untreated (b) treated



(a)



(b)

Fig. 3: Scanning electron micrographs of pumpkin skin powder (a) untreated (b) treated

Optimisation of Baking Temperature and Time of Pumpkin 'Bingka' using Response Surface Methodology

It is confirmed that the fitted model from the ANOVA data is suitable because it shows a significant regression, low residual values, no lack of fit with satisfactory determination coefficients (R^2) of 0.946 to 0.9988 for the responses including moisture content, hardness, and chewiness from the 'bingka' made by fresh sample and powder, as well as unpeeled and peeled samples. The value of R^2 should be close to 1 for a good statistical model. The model terms are more significant for lower p value. The p value of less than 0.05 suggests that the model term is significant (Ghodke *et al.*, 2009).

Effects of Baking Temperature and Time on Moisture Content

Table 4 presents the effects of baking parameters (temperature and time) on moisture content, hardness, and chewiness for the samples baked by using an air fryer. Firstly, moisture content is the most essential criterion and it is closely associated with the quality and texture of pumpkin 'bingka'. Before baking, the initial moisture content of the batter was standardised to the value of $48.75 \pm 0.12\%$ (wet basis). The final moisture content of all the 'bingka' samples is between 30% and 45% (wet basis) (Table 4). The 'bingka' baked at 150°C in the air fryer resulted in low moisture content (30.60%) at 35 min as compared to baking at a lower temperature (130°C) (Table 5).

The highest moisture content was recorded for the sample baked at 130°C for 25 min. The moisture content of baked 'bingka' was observed for the sample made from peeled and unpeeled fresh pumpkin (45.92% and 43.47%, respectively). The moisture contents of the 'bingka' made by using the powder from peeled and unpeeled pumpkin are 44.23% and 44.47%, respectively. It is observed that the 'bingka' made from peeled pumpkin and peeled pumpkin powder has the highest value of moisture content compared to the 'bingka' made from unpeeled pumpkin. This is due to the texture of pumpkin that peeled pumpkin is from flesh of pumpkin whereas unpeeled pumpkin its combination of flesh and skin pumpkin.

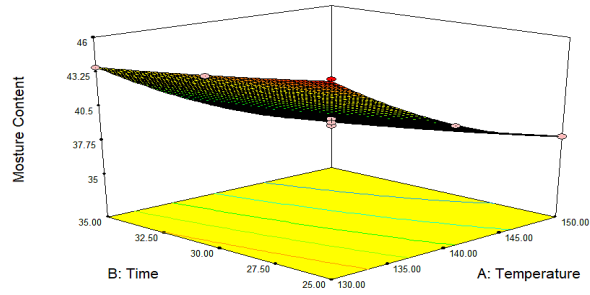
Baking temperature will affect the highest or lowest condition on moisture content of pumpkin 'bingka'. The only temperature is highly significant effect ($p < 0.05$) on moisture content for each sample. The air flow in the air fryer significantly influenced the baking temperature as well. A higher baking temperature meant that more heat was transfer to the 'bingka' surface. Thus, an increase in the moisture content of baked pumpkin 'bingka' could have led to an increase in the hardness of the products. It can be acknowledged that moisture content is significantly influenced by temperature and time.

From Figure 4 (a), there might be shorter baking process occurring as the response surface plot increases consistently compared to Figure 4 (b).i. It means that a temperature increase during baking process reduces the rate of heat penetration into the 'bingka'. It can be related that longer contact time of a cake in an oven causes more evaporation of water vapour (Alifaki and Şakıyan, 2016). The decreasing amount of heat penetrating through the 'bingka' becomes a restrictive factor, thus slowing the moisture vapour generation in the 'bingka' batter (Shahapuzi *et al.*, 2015).

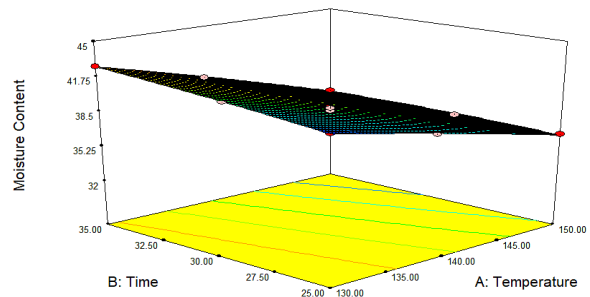
Effects of Baking Temperature and Time on Hardness

The determination of the hardness requires compression of the sample using force (N) by setting the product distance (Al-Muhtaseb *et al.*, 2013). The effects of time and temperature on hardness are shown in Table 4. Baking temperature and time have a significant effect on the hardness of 'bingka' made from unpeeled pumpkin and peeled pumpkin powder ($p < 0.05$) baked using the air fryer.

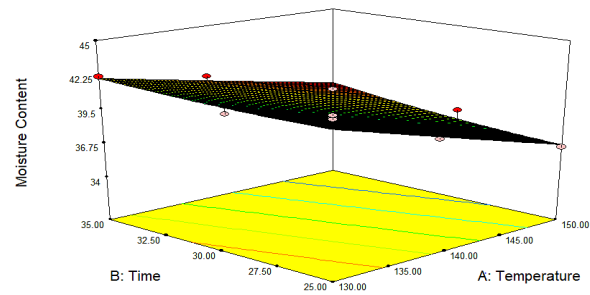
Figure 5 shows that all graphs are negatively quadratic. The same pattern in the said graphs may be due to the initial increase and subsequent decrease in the heat transfer and time gap during the baking of 'bingka'. When the pumpkin 'bingka' is baked at a higher temperature for a longer time, its hardness will increase. This is due to the circulation of superheated air, in which the baking chamber receives heat from a heating element close to the 'bingka' (Rahman *et al.*, 2016).



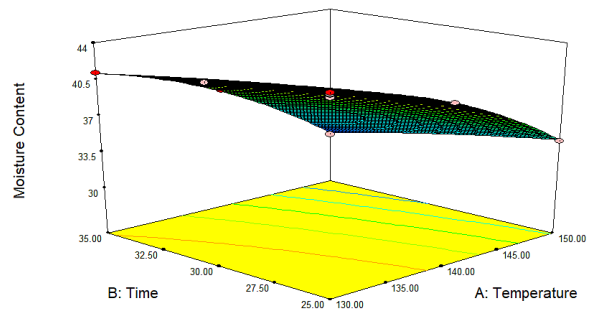
a (i)



a (ii)



b (i)



b (ii)

Fig. 4: Response surface plot of the effect of temperature and time on the moisture content of 'bingka' made from a (i) peeled pumpkin, a (ii) peeled pumpkin powder, b (i) unpeeled pumpkin, and b (ii) unpeeled pumpkin powder

Table 4: Experimental design and data obtained for the response variables of pumpkin 'bingka' baking

Run Parameters	Responses																
	Peeled Pumpkin				Unpeeled Pumpkin				Peeled Pumpkin Powder				Unpeeled Pumpkin Powder				
Temperature (°C)	Time (min)	MC (%)	Hardness (N)	Chewiness (N)	MC (%)	Hardness (N)	Chewiness (N)	MC (%)	Hardness (N)	Chewiness (N)	MC (%)	Hardness (N)	Chewiness (N)	MC (%)	Hardness (N)	Chewiness (N)	
1	130	25	45.92	8.55	2.95	43.47	8.43	3.03	44.23	8.76	3.49	44.47	8.58	3.37	44.47	8.58	3.37
2	130	30	44.55	8.96	3.48	42.28	9.56	3.84	43.59	9.74	4.02	43.78	9.71	3.79	43.78	9.71	3.79
3	130	35	43.63	9.92	4.36	41.18	11.83	4.93	42.72	10.78	4.82	42.18	10.74	4.34	42.18	10.74	4.34
4	140	25	40.84	11.52	5.25	40.47	12.41	5.41	40.39	11.38	5.73	41.27	11.62	4.96	41.27	11.62	4.96
5	140	30	40.62	12.36	5.96	39.35	13.06	6.79	38.64	12.46	6.12	39.95	12.69	5.3	39.95	12.69	5.3
6	140	30	39.9	12.53	6.04	38.85	13.99	6.31	38.91	12.66	6.57	38.85	13.48	5.81	38.85	13.48	5.81
7	140	30	39	12.03	6.58	39.08	14.06	6.57	39.18	11.89	6.88	39.08	12.85	6.25	39.08	12.85	6.25
8	140	30	39.56	12.15	6.34	39.26	14.14	6.93	39.89	12.63	6.32	39.46	12.33	6.44	39.46	12.33	6.44
9	140	30	39.25	12.19	6.81	39.16	14.67	6.05	39.24	12.39	6.59	38.75	13.02	6.93	38.75	13.02	6.93
10	140	35	38.98	13.42	7.34	37.49	15.1	7.49	37.45	13.22	7.21	37.41	13.82	7.24	37.41	13.82	7.24
11	150	25	38.12	13.79	7.97	34.65	15.16	7.92	36.46	13.75	7.4	36.49	14.05	7.83	36.49	14.05	7.83
12	150	30	37.12	14.23	8.35	33.29	15.38	8.01	34.19	14.07	7.76	35.23	14.73	8.09	35.23	14.73	8.09
13	150	35	35.6	14.7	8.94	30.6	15.67	8.7	33.06	14.48	7.98	34.6	15.56	8.31	34.6	15.56	8.31

Table 5: Analysis of variance of the responses by quadratic regression model

Sources	Peeled Pumpkin		Unpeeled Pumpkin		Peeled Pumpkin Powder		Unpeeled Pumpkin Powder	
	MC	Hardness	Chewiness	MC	Hardness	Chewiness	MC	Hardness
Model	< 0.0001*	< 0.0001*	< 0.0001*	< 0.0001*	< 0.0001*	< 0.0001*	< 0.0001*	< 0.0001*
A-Temperature	< 0.0001*	< 0.0001*	< 0.0001*	< 0.0001*	< 0.0001*	< 0.0001*	< 0.0001*	< 0.0001*
B-Time	0.0011*	0.0001*	0.0010*	0.0006*	0.0001*	0.0009*	0.0007*	0.0002*
AB	0.8279**	0.3588**	0.5383**	0.1333**	0.0055*	0.1794**	0.7338**	0.366**
A ²	0.0114*	0.0016*	0.1418**	0.0535**	0.4959**	0.0065*	0.5856**	0.8704**
B ²	0.7123**	0.2309**	0.8461**	0.7534**	0.5854**	0.0277*	0.9337**	0.8143**
Lack of fit	0.8994	0.2679	0.5671	0.6162	0.9511	0.9886**	0.2958	0.9423
R ²	0.982	0.989	0.986	0.974	0.993	0.972	0.978	0.975

*significant ($p < 0.05$); ** not significant ($p > 0.05$)

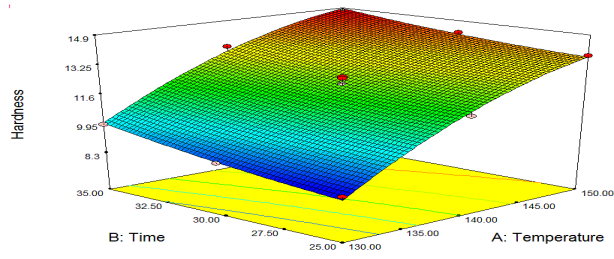
Effects of Baking Temperature and Time on Chewiness

Chewiness is the force required to chew a solid food until it is ready for swallowing (Al-Muhtaseb *et al.*, 2013). From the collected data, it can be said that with the increase of baking temperature and time, the hardness of 'bingka' will increase, hence producing an increment in the force required to chew the 'bingka' until it is ready for swallowing. The highest value of chewiness is 8.94 N for the 'bingka' made from peeled pumpkin baked at 150°C for 35 min. This is because the heating rises faster at high baking temperature, resulting in the increase of the chewiness of pumpkin 'bingka'.

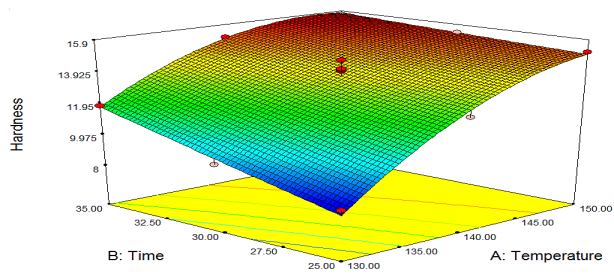
Baking temperature is found to significantly affect the chewiness of the pumpkin 'bingka'. Lower temperature during baking would produce softer texture and less chewy pumpkin 'bingka'. Based on Figure 6, baking temperature of 130°C and baking time of 25 min, as well as fresh unpeeled pumpkin 'bingka' resulted in the lowest value of chewiness (3.03N). Evidently, the addition of powdered pumpkin flesh and skin will affect the texture of the product. However, at the same temperature and time as mentioned above, the chewiness of unpeeled pumpkin powder 'bingka' is higher than that of the peeled pumpkin powder product, as shown in Figure 6 b (ii) and Figure 6 a (ii). At higher temperatures, more moisture is lost due to evaporation; hence, the firmness increases and more chewing are required to swallow the 'bingka'.

Table 6: Criteria and outputs for numerical optimization of pumpkin cake

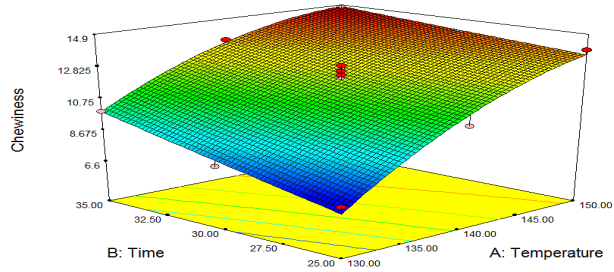
Criteria	Goals	Limit
Temperature (°C)	Minimize	130 – 150
Time (min)	Minimize	25 – 35
Moisture Content (%)	in the range	38 – 42
Hardness (N)	in the range	10.0 – 11.5
Chewiness (N)	in the range	3.0 – 4.5



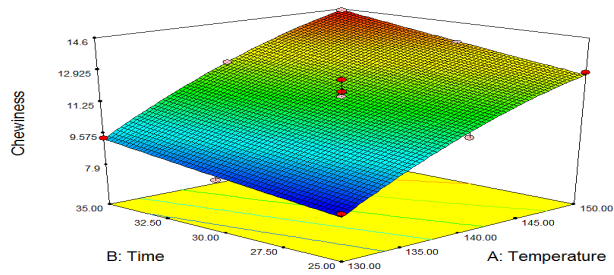
a (i)



a (ii)



b (i)



b (ii)

Fig. 5: Response surface plot of the effect of temperature and time on the hardness of 'bingka' made from a (i) peeled pumpkin, a (ii) peeled pumpkin powder, b (i) unpeeled pumpkin, and b (ii) unpeeled pumpkin powder

Table 7: Predicted and experimental values of the response variables at optimum formulation

Sample	Temp	Time	MC (%)	Hardness(N)		Chewiness (N)		% error		
				%	Hardness(N)	%	Chewiness (N)			
PP	130	25	41.89	40.36 ± 0.24	1.17 %	11.30	11.45 ± 4.30	1.31%	3.31 ± 0.32	1.20%
	130	25	41.86	42.38 ± 0.40	3.58 %	10.90	10.68 ± 0.86	2.01%	3.16 ± 0.53	1.25%

** PP- Peeled Pumpkin; UP- Unpeeled Pumpkin; PPP- Peeled Pumpkin Powder; UPP- Unpeeled Pumpkin Powder

Optimisation and Validation of the Data

Based on the discussion and the results, it can be concluded that the criteria of all independent variables are very important in defining the characteristics of 'bingka'. The best combination of the factors is

able to produce the expected characteristics of the final 'bingka'. The optimisation of baking conditions arises from compromises among different responses (Das *et al.*, 2012). The criteria of optimisation should be selected and each response variable may either be minimised or maximised.

The moisture content and of commercial value of pandan 'bingka' was 43.6 ± 0.65%, pumpkin 'bingka' 44.28 ± 0.13%. The ranges selected as the goals for each criterion with some alterations are tabulated in Table 6 . Each variable is defined to produce the best quality of powder.

The values of limitation of moisture content, hardness and chewiness were based on preliminary experiment and local and product. The 'bingka' baked at minimum baking time and temperature has higher moisture content of 45.78 ± 0.03 at lower hardness. Overall, the moisture content and hardness are acceptable for a presentable 'bingka' made from peeled and unpeeled pumpkins. The predicted and experimental results showed that the percentage errors are less than 10%; therefore, the response model has a valid prediction (Siti Faridah & Noor Aziah, 2012).

Colour of Pumpkin 'Bingka'

Table 8 shows the values of the tristimulus colour parameters of L^* , a^* , and b^* , as well as ΔE of pumpkin 'bingka'. The L^* values of the 'bingka' made from peeled and unpeeled pumpkin powder are 61.51 ± 0.26 and 63.10 ± 0.32, respectively, whereas the L^* values of the 'bingka' made from peeled and unpeeled pumpkins are 60.09 ± 0.57 and 63.67 ± 0.43, respectively. These results are expected because they are similar to the colour of a fresh pumpkin. The colour of fresh pumpkin flesh is about 67.94, according to the L^* parameter (Norfezah *et al.*, 2011).

According to the experimental results, the ΔE values of the 'bingka' baked in the air fryer are from 11.26 to 11.88 (Table 8). The increased values of ΔE are obtained due to higher temperature, especially with the airflow of the air fryer. According to the statistical analysis, baking temperature and time are significant criteria for the colour change of the 'bingka'.

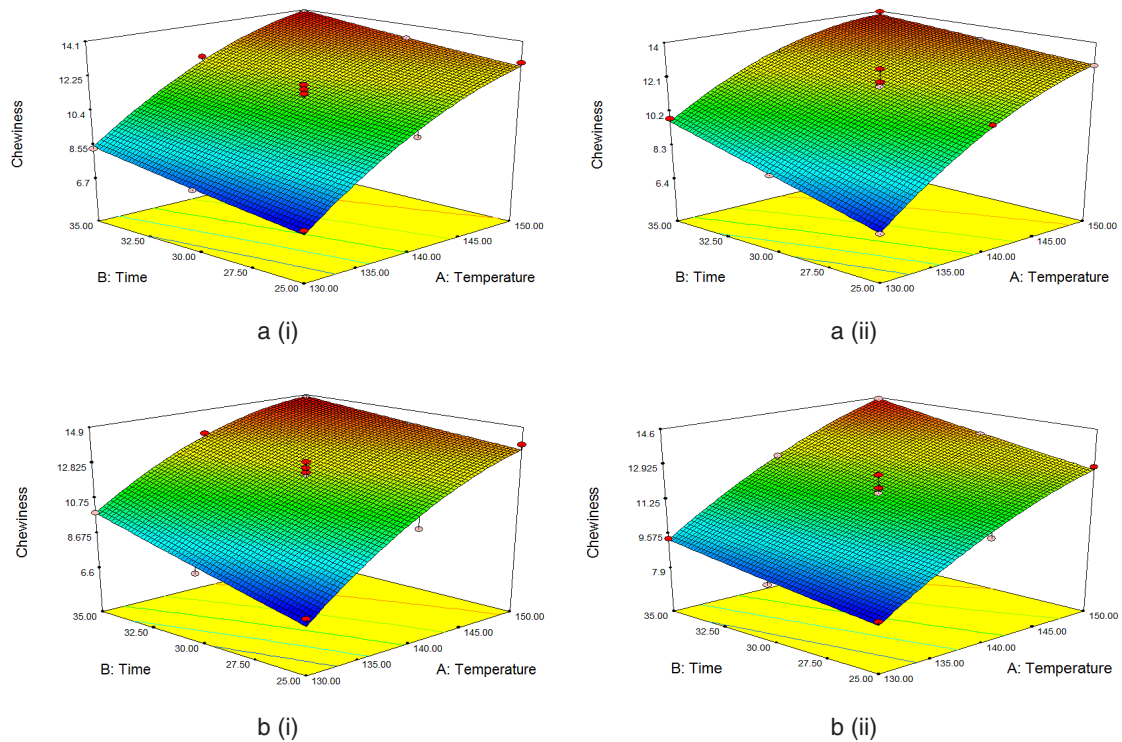


Fig. 6: Response surface plot of the effect of temperature and time on the chewiness of 'bingka' made from a (i) peeled pumpkin, a (ii) peeled pumpkin powder, b (i) unpeeled pumpkin, and b (ii) unpeeled pumpkin powder

Conclusions

The moisture content of treated samples are 5.18%, 5.56%, and 4.93% for peeled pumpkin, unpeeled pumpkin, and pumpkin skin, respectively. The limewater pre-treatment was observed in moisture content, water activity, particle size and morphology reduction in all sample pumpkin powder after drying as compared to control sample control powder.

It was observed that peeled pumpkin powder, unpeeled pumpkin powder and skin pumpkin powder that were pre-treated with limewater have a good quality in terms of moisture content, water activity, particle size, colour and structural morphology. Pumpkin powders produced under optimum operating parameters were applied in 'bingka' as a substitute for fresh pumpkin. Pumpkin powders produced under optimum operating parameters were then applied in 'bingka' as a substitute for fresh pumpkin. Baking temperature and time affect the

moisture content and texture of peeled and unpeeled pumpkin 'bingka'. Baking temperature and time show significant effect ($p < 0.05$) on the moisture content and hardness of all samples, except for those made from fresh pumpkin, unpeeled pumpkin, and peeled pumpkin powder.

The production of pumpkin powder have a good benefit to industry due to perishable raw pumpkin was produce to product that longer shelf life. Drying constitutes an alternative way to increase the consumption of pumpkin and allows its use during off-season.

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Conflict of Interest

The authors were declares no conflict of interest.

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