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Effect of Stage of Maturity and Frying Time on the Quality of Banana Springs

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ABSTRACT

Banana springs are a new snack food similar to banana chips. This study focuses on the quality improvement of banana springs. The effects of stage of maturity and time of frying on the quality of banana springs prepared from two varieties namely, *Musa acuminata* Colla cv. Berangan and *Musa paradisiaca* L. *cv.* Nangka, were evaluated. Five stages of maturity, i.e., i) mature, ii) early ripening, iii) intermediate ripening, iv) ripe, and v) overripe, were used in the trial. The total soluble solid (TSS) of two varieties at different maturity stages was measured. Banana springs were made by using spiral potato slicer. The slices of banana spring were 2±0.1 mm in thickness. The banana springs were deep fried in refined, bleached and deodorised (RBD) palm olein at a temperature of 170°C for 0, 3, 4, 5, and 6 minutes respectively. The fried banana springs were tested for their texture and crispiness. The samples were assessed for colour, flavour, texture, taste and overall acceptability by a 30-member taste panel. The TSS content of Nangka banana was greater than Berangan banana and the TSS content increased with maturity but it was a bit different between two varieties. Banana springs of Nangka variety had a higher value for texture (hardiness), especially at the early maturing stages in comparison to Berangan banana. Frying of banana springs for five and six minutes produced the same

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quality. An acceptable product with good taste, crispness, and the odour was obtained from both the varieties when fried at 170°C for 5 minutes. Nangka banana was better in respect of sweetness, odour, texture, and crispness vis-a-vis Berangan. Green matured banana (Maturity index I) of both the varieties was found suitable for the preparation of quality banana springs.

Keywords: Banana springs, banana variety, banana maturity index, berangan banana, frying time, nangka banana, sensory evaluation, total soluble solids

INTRODUCTION

Banana (*Musa sp.)* is an important source of carbohydrates, nutrients, minerals and fibre content (Robinson & Sauco, 2010). It is a low-cost food that serves as the primary food source in many developing countries including East African countries, Bangladesh and Malaysia (Mohapatra, Mishra, & Sutar, 2010). In Malaysia, banana covers more than 11% of the total area for fruit production and is a premier fruit, ranking second after durian. The annual production of banana in the 2014 was 303,107 tonnes and the area covered was 28,911 ha (FAOSTAT, 2017). But it is a perishable fruit, and it has a short lifespan between harvest and onset of deterioration. Therefore, it is essential to process the fruit into different downstream products to maximise its use. Usually, banana is processed into banana chips, French fries, banana powder and flour, banana cocoa, and coffee, alcohol, wine, and vinegar worldwide. There are many ways of processing and consuming banana in Malaysia, such as banana chips, which is one of the favourite snacks in the country. Borah and Nayak (2013) studied the drying behavior and quality of dried and fried banana chips in India. They observed that the effects of drying temperature, moisture content, and frying time on the hardness of chips were significant. Chips' thickness, frying temperature and frying time influenced the crispness, colour development and overall acceptance of banana chips as well (Wani, Sharma, & Kumar, 2017). They noted greater acceptance of banana chips with increased frying time. Banana springs are a similar kind of product made just like spiral springs using a slicer and then fried in hot oil at 130°C to 180°C. The demand for snack food is increasing in Malaysia since the number of working women who spend less time cooking is increasing (Norrita, 2015). Banana springs can be a rich source of nutrition though it is a snack.

Some studies have examined the effects of temperature, drying, breading of fried banana products and oil deterioration (Borah & Nayak, 2013; Wani et al. 2017; Zainun, 2008). However, very little attention has been given to the effects of the variety of banana and their stages of ripening on the quality of fried banana springs. The impacts of frying time on the quality of banana springs are also not well explored. Therefore, this investigation was done to study the effects of stages of ripening and frying time on crispness and taste of banana springs made from two banana varieties. It also assessed the overall acceptability of the deep-fat fried product.

MATERIALS AND METHODS

Fifty matured banana fingers (unripen green) of equal size (Berangan = 120 g ± 0.95; Nangka = 128.5 g ± 0.26) of two varieties, namely Berangan banana (*Musa acuminata* Colla cv. Berangan) and Nangka banana (*Musa paradisiaca* L. cv. Nangka) were bought from a local market. The banana varieties were identified based on their physical appearance. Berangan banana (Chestnut banana) has medium-long fingers, rounded in cross-section, parallel sided with apex usually rounded, and flesh is sweet; whereas Nangka banana (Jackfruit banana) are medium-long, rounded to slightly angular in cross-section, with apical teats and pulps are sour-sweet (Figure 1) (Casey, 2015). Refined, bleached and deodorised (RBD) palm olein (Brand: Saji) was obtained from the "Pantai Timur" supermarket, Jeli, Kelantan, Malaysia. Bamboo sticks (15 cm long and 2.5 cm diameter) were purchased from a local market.

Determination of Ripening Stage of Banana

The banana fingers were kept in a store room after wrapping them with plastic. They were allowed to ripen slowly under a room temperature of 25°C, relative humidity of 80%-85% until they reached the desired different stages of ripeness. No ripening agent was used. The stage of ripening of fresh banana was determined according to Caussiol and Joyce (2001) and Mba, Rahimi and Ngadi (2013) by using a colour chart and other physical observation. The ripeness of banana was assessed by comparing the colour of their peel and hardness with standardised banana maturity index as described in Table 1.

Determination of Total Soluble Solids (TSS)

Banana solutions were prepared by grinding 10 g of peeled banana sample with 50 ml of distilled water in a blender for 5 minutes and was filtrated to remove the solid particles. The TSS (Brix) was measured on the filtrate using the Atago Master-Alpha Refractometer (Agriculture Solutions LLC, Strong, ME, USA) at room temperature.

(a)

(b)

Figure 1. Photographs of: (a) Berangan banana; and (b) Nangka banana at early maturity stage (II)
Source: Casey, 2015

Table 1

Description of ripening stages and maturity index of banana

Maturity index	Storage day	Ripening stage	Colour of the peel
I	1	Mature	All peels are green
II	3	Early ripening	Green peel with a trace of yellow
III	7	Intermediate ripening	More green area than yellow
IV	9	Ripe	All yellow colour
V	11	Overripe	All yellow with brown speckles

Modified from Caussiol and Joyce (2001), and Mba et al. (2013)

Preparation of Banana Springs before Frying

The banana samples of two varieties were washed and manually peeled. The peeled banana (banana pulp) was sliced to a thickness of 2 ± 0.1 mm by using a Spiral Potato Slicer (MyDeal.lk Pvt. Ltd., Galle Road, Colombo 04, Sri Lanka). First, a bamboo stick was pierced through the peeled banana. It was placed on the slicer and by moving the handle of the slicer the banana springs were made. Twenty springs were pre-treated by soaking them in acidified water (a 1% solution of ascorbic acid) to prevent them from browning. The treated banana springs were blotted with blotting paper to dry out excess surface water from banana springs before frying. They were partially dried in a drying cabinet at 60°C for 15 minutes when the moisture content was reduced from 70.0% ± 2.1 (initial moisture) to 36.0% ±1.2, since dehydration of banana slices before frying improves the quality of banana chips (Agunbiade, Olanlokun, & Olanofe, 2006). The banana springs were fried in a deep-fat fryer (HKH-JB-ZL74 5.5L, HIKITCH Kitchen Equipment Co. Ltd., China) using palm olein at a temperature of 170°C ± 2°C. The RBD palm olein has essential characteristics of industrial frying oils such as high oxidative stability, high smoke point, low foaming, low melting point, bland flavour and nutritionally desirable attributes (Kochhar, 2000). The fryer had temperature control (range: 0°C to 200°C) and a perforated frying container. The deep-fat-fryer was set to the target temperature and was pre-heated to 170°C ± 2°C for one hour before the frying started. Four litres of fresh vegetable oil, RBD palm olein, (Free Fatty Acid (FFA) = 0.15% and Peroxide Value (PV) = 1.2 meq H_2O_2/kg oil, smoking point = 220°C) were used in all experiments. As per Kochhar (2000) good industrial frying oil should have less percentage of FFA, PV, and high smoke point (above 180°C) with a bland flavour. Oil temperature was measured by a thermometer held in a position 5 mm below the spring edge. The banana springs were divided into five different portions and were fried for 0 (control), 3, 4, 5 and 6 minutes. Five springs were put into sample holders, which were immersed completely in the hot oil. Fresh oil was used every time for

frying banana springs of both the varieties, Berangan and Nangka. After each frying, the banana springs were shaken well to drain out surface oil adhering to the surface of banana springs and lastly was blotted with a paper towel. The fried banana springs were allowed to be cooled for 10 minutes at room temperature before being tested for crispness and sensory evaluation. The fried samples were stored in an air-tight container before texture testing. The experiments were carried out in triplicates.

Texture Test

Compression/puncture test using a Testometric Universal Testing Machine (Testometric Company Ltd., Rochdale, UK) was done at room temperature immediately after frying to know the textural hardness and crispness of the fried banana springs. The puncture test was done by mounting the sample (a single spiral piece just like a banana chip) on a flat rigid support where the distance between the support and a cylindrical punch was 15mm. The punch diameter was 5.3 mm, and the crosshead speed was 25 mm min^{-1}. The force was applied to the fried banana springs until those were broken. Maximum breaking force (mm/minute) and deformation (mm) were measured. Normalised Maximum Force, measured in Newton (N) was the parameter used to measure the textural hardness (equals maximum force/maximum deformation) (Mba et al., 2013).

Sensory Evaluation

Sensory evaluation was done following the method of Ali, Muhammad, Sijam and Siddiqui (2011). The samples were assessed for colour, flavour, texture, taste and overall acceptability by a 30-member taste panel from the Universiti Malaysia Kelantan's lecturers, staff and students using a 9-point hedonic rating scale, where 1= dislike extremely and 9 = like extremely. Before the actual sensory evaluation, the panel was informed and instructed for the sensory attributes in the assessment to familiarise with the sensory procedure. The products were presented to the panellists after frying in refined palm olein for different periods as per treatment specification. The panellists were provided with a form which had the columns of all the attributes along with the column of overall acceptability for putting the sensory scores against different quality attributes of the banana springs. Data were tabulated properly for statistical analysis.

Experimental Design and Statistical Analysis

The effects of banana variety, stage of ripening, and frying time on the colour, odour, taste, texture, crispness of the banana springs were evaluated using a factorial design, with 2 levels for variety, five levels for the stage of maturation, and four levels for frying time. The effects of variety and ripening stages were analysed first. After selecting appropriate maturity based on brix% and texture, the effects of frying time were tested on two varieties. In case of evaluation of TSS contents, only the

effects of variety and stage of ripening were considered and therefore two-factor design was used, and data was analysed using two-way analysis of variance (ANOVA). The regression analysis between TSS content and stage of maturity (over time) has been done. Sensory data presented here are the means of three replicates. Data was subjected to descriptive analysis, where maximum, minimum and mean values were determined. One-way ANOVA was also done to determine if the samples were significantly different (Fetuga, Ajayi, & Karim, 2014). All the experiments were carried out in triplicates following the Completely Randomised Design. Data was analysed statistically using SPSS software. Duncan's multiple range tests were used to indicate the place of significant differences among the means at 5% probability level.

RESULTS AND DISCUSSION

Effect on Total Soluble Solids (TSS)

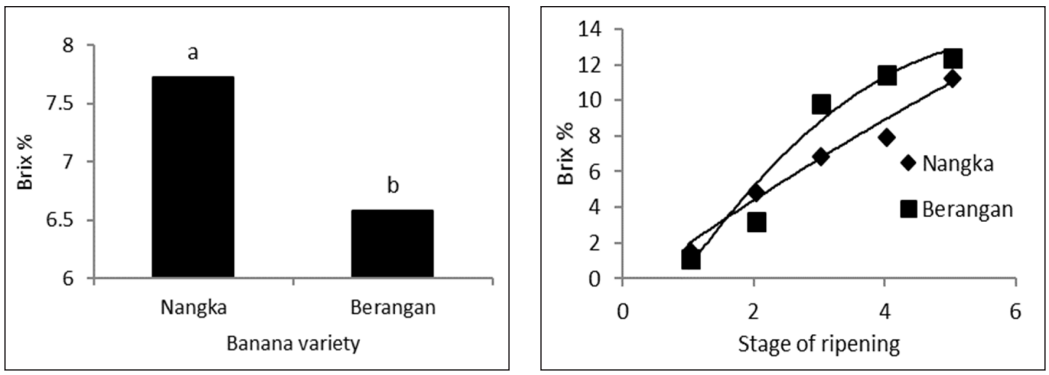
The results shown in Table 2 indicate the range of TSS and the effects of variety and stages of ripeness on the total soluble solid (TSS) value of fresh banana, while Figures 3 and 4 indicate the effects of variety and stage of ripening on texture/crispness of banana springs. Although the TSS usually increases with the maturity of banana (Wanna, Yaakob, Salmah, & Russly, 2001) a comparison was made between two varieties to see the trend and level of increase in TSS which might affect the quality of banana springs.

Effect of Variety. Figure 2A shows the mean Brix% for Nangka banana and Berangan banana. The results indicate there is a significant ($P < 0.05$) difference in TSS contents of the fresh banana of two varieties, and Nangka banana contained higher TSS than Berangan banana.

It is evident that on average, the Nangka banana contained about 15% more TSS than the Berangan banana, which might be due to their differences in plant genetics. Wanna et al. (2001) compared the physicochemical properties of Nangka banana with Abbu banana and found that Abbu banana had greater carbohydrate content than Nangka banana. However, Zainun (2008) noted the higher amount of TSS and total sugar contents in Nangka compared with Berangan, Raja and Mas varieties. The sugar content of banana varieties may vary due to edaphic and climatic differences as well (Rajkumar, Wang, EImasry, Raghavan, & Gariepy, 2012). The upward direction of successive data points indicates that the TSS increased with maturity. However, the regression equation is more fit to polygonal. The regression equation for Berangan banana is $Y = -0.517X^2 + 6.18X – 5.118$; $R^2 = 0.947$ and that of Nangka banana is $Y = - 0.063X^2 + 2.635X -0.63$; $R^2 = 0.974$. The overall increase of TSS was greater in Berangan banana than that of Nangka banana (Figure 2(b)).

Effect of Ripening Stage. Table 2 shows that there is significant ($P < 0.05$) difference in total soluble solid contents among the maturity stages of banana in both

the varieties. The TSS contents of both the varieties increased linearly with the advancement of ripening stages. However, the trend of increase with maturity was different in two varieties (Figure 2(b)). The increase in total soluble solid is related to fruit ripening which involves the conversion of starch to sugar in ripen banana. During the ripening process, hydrolysis of starch takes place, and it causes the accumulation of sugar. Other changes that happen during ripening include alteration of cell structure, changes in cell wall thickness, the permeability of the plasma membrane, hydration of the cell wall, decrease in structural integrity and increases in intracellular spaces. Rajkumar et al. (2012) observed polynomial relationship (i.e., first increased and then reduced) between maturity stages and TSS content of banana, which was modified due to temperature differences.



(a) (b)

Figure 2. (a) Effects of banana variety on the total soluble solid content (Dissimilar letters on the histograms indicate significant difference); (b) Effects of stage of maturity on the total soluble content of two banana varieties. The continuous thin lines indicate the polynomial relationship.

Interaction Effect of Variety and Stage of Ripening. Table 2 shows the values of TSS under different stages of ripeness of two banana varieties. However, the rate of increase was unusual in two varieties. For example, the rate of TSS increase in Berangan banana was low initially, but it increased at the later stage even more noticeably than the Nangka variant. In case of Nangka banana, the rate of increase was more or less linear maturity of banana (Figure 2(b)). There are differences between banana and plantains in starch contents. Plantains are the members of the banana family, but these fruits have more starch and less sugar than the banana and usually are cooked before serving. Marriott, Robinson and Karikari (1981) stated that fully ripe bananas have 1% starch but it contained 0% starch when overripe. In case of plantains, it contains 9% starch at the fully ripened stage and 3% starch at the over ripen stage

of maturity. In an investigation, Marriot et al. (1981) observed that bananas had 23% sugar at ripening or over ripen stage, but the plantain had 20% sugar at ripe and 27% at the overripe stage of ripening.

Effect on Texture

It is evident that the formation of crispness in potato and banana chips occurs at the end of frying (Wanna et al., 2001). Therefore, texture analysis as a function of frying time was done at the end of frying. The maximum breaking forces for banana springs fried at four different frying times (3, 4, 5 and 6 minutes) were compared using the two banana varieties and five maturity stages separately. The initial moisture of banana springs (70.0%) was reduced to 36.0% by drying at 60^{o}C for 15 minutes.

Effect of Variety. Table 2 and Figure 3 indicate that there is significant ($P < 0.05$) variation in the texture of banana springs of the test varieties of banana. A clear difference between maximum braking forces of banana springs was observed between Nangka and Berangan banana.

It is obvious that the banana springs of Nangka variety had a higher value for texture (hardiness), especially at the early maturing stages in comparison to Berangan banana (Figure 3(a)). The main difference in hardiness between the varieties is due to the differences in carbohydrate contents. Therefore, Nangka banana springs were crispier than Berangan banana. Elfnesh, Tekalign and Solomon (2009) noted a negative relationship between crispness of potato chips and dry matter contents of the potato cultivar.

Effect of Ripening Stage. There was a significant ($P < 0.05$) linear decrease in texture value (N) with the advance of maturity stages in both the varieties (Table 2). Negative correlations were noticed between the maximum breaking force and the stage of maturation of banana. As the starch content is converted to sugar and hydrolysis take place in the advanced maturity stage of banana, hardiness of banana springs was reduced at later maturity stages (Elfnesh et al., 2011). It might be the result of the breakdown of carbohydrates during respirations, and the hydrolysis of starch which leads to transfer of moisture from peel to pulp (Cano et al., 1997).

An optimal maturity stage was recognised when the maximum breaking force (1.8 N) of the springs was the highest. This point corresponded to maturity index of I – Green matured stage (Table 2). After this ripening stage, the carbohydrate was converted to sucrose and flesh of banana become soft which lead to poor quality of springs. Ammawath, Yaakob, Yusof and Rahman (2001) also marked that the crispness of banana chips was reduced with the ripeness of the Abu banana.

Effect on Crispness

Effect of Variety. The crispness is one of the textural qualities of fried food products. Loudness, snap, crackly, firmness, etc. are the examples of other texture qualities (Vickers & Christensen, 1980). During

frying process, the banana chips or springs lose the moisture from about 90% to 5%, and it absorbs the oil in the pores due to evaporation of moisture. Finally, these chips become crispy (Borah & Nayak, 2013). In this study, texture and crispness were measured following the same procedure. The statistical analysis of the results showed that banana springs produced from Nangka banana were significantly crispier ($P<0.05$) than the banana springs produced from Berangan banana (Figure 4 (a)). It might be because Nangka fresh banana had a higher total soluble solid content and was harder compared with Berangan banana. It was supported by Ammawath et al. (2001) who reported that fresh banana with higher carbohydrates content and fruit firmness gave chips with greater crispness.

Table 2
Interaction effects of banana variety and the stage of maturity on texture of banana springs and total soluble solid

Variety	Stage of Ripeness	Texture (N)	Total Soluble Solid (Brix %)
Berangan	Matured	1.74^{a}	1.63^{e}
	Initial Ripening	1.56^{b}	4.93^{d}
	Intermediate Ripening	1.45^{c}	6.96^{c}
	Ripe	1.34^{d}	8.03^{b}
	Overripe	1.13^{e}	11.37^{a}
Nangka	Matured	1.77^{a}	1.27^{e}
	Initial Ripening	1.76^{b}	3.33^{d}
	Intermediate Ripening	1.44^{c}	9.93^{c}
	Ripe	1.12^{d}	11.60^{b}
	Overripe	0.71^{e}	12.50^{a}
Min		0.71	1.27
Maximum		1.77	12.50
Mean		1.168	5.962
SD		± 0.25	± 2.53

Values in columns having dissimilar letter indicate significant differences

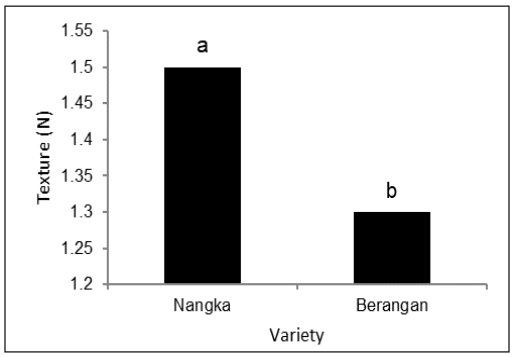


Figure 3. Effects of banana varieties on the texture (measured in Newtons) of banana springs (The dissimilar letters on the histograms indicate significant difference)

Effect on Frying Time. The results in Figure 4 show that there was a significant increase in crispness at every increase during the time of frying. The effects on two varieties are more or less similar. The regression equation for Berangan banana is $Y = 0.331x + 3.43$, $R^2 = 0.989$ and for Nangka banana it is $Y = 0.301x + 3.365$, $R^2 = 0.965$. The crispness score was the highest under 6 minutes frying time. However, no significant difference is noted in crispness between banana springs fried for 5 and 6 minutes respectively (Figure 4(b)). The crispness or hardiness increased during frying due to the crust development.

The frying process results in unique flavour, colour, and texture which affect consumer acceptability. The texture of the banana spring is an essential sensory parameter that determines the sensory acceptability and shelf stability. Since the same kind of quality found under frying for 5 and 6 minutes, 5 minutes frying is recommended for saving time, cost and energy.

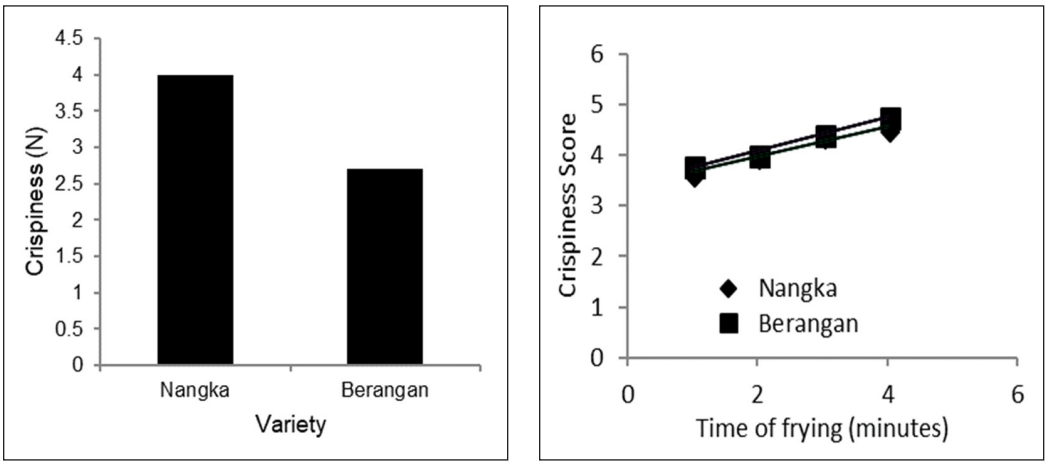
Acceptance by Consumers

The overall acceptability scores of fried banana springs of two varieties are shown in Figure 5. Results in Table 3 show the information on the sensory evaluation of different sensory attributes and overall acceptability of banana spring produced by deep-fat frying for varying periods of time.

For sensory evaluation, only banana at green mature stage (Maturity index I) was used to make banana springs. It is because in texture test, it proved that ripe green banana (Maturity index I) is the best stage for preparation of banana springs. The quality attributes of banana springs, especially its odour, texture, crispness, etc. produced after frying for different periods of time are reflected on the overall acceptability of products by the panellists. The panellist's scores for total acceptance for banana springs ranged from good to very good scale. None of the samples was rated as poor quality. It indicates that consumers may not reject banana springs though they are accustomed to banana chip or potato chip. There were significant differences ($P < 0.05$) between Berangan banana springs and Nangka banana springs fried at different times of frying in overall acceptability. However, no significant differences were noticed between two varieties in sweetness and odour of banana springs (Table 3). Moreover, Nangka banana springs fried for 5 minutes had a higher acceptability score (although non-significant) than frying for 6 minutes. In case of Berangan banana springs, the acceptability score when fried for 6 minutes was higher, but there was no significant difference between 5 and 6 minutes drying (Table 3).

Therefore, frying banana springs of both the varieties for 5 minutes (Figure 6) is recommended to save time and energy. Aurore, Purfait and Fahrasmane (2008) commented that it is important to generate new knowledge about bananas and banana products to improve their consumption and to explore the possibility of more agri-

businesses with banana products. This result provides information on the possibility of commercial production of banana springs to add new banana products in the food market. However, no comparison was done with other similar products in this study, which could be done in future.



(a) (b)

Figure 4. (a) Effects of banana variety on crispness of banana springs (The dissimilar letters on the histograms indicate significant difference). (b) Effects of time of frying on the crispness of banana springs of two banana varieties. Note that the effects are more or less similar on both the varieties. The continuous thin lines indicate the linear relationship.

Table 3
Interaction effects of banana variety and time of frying on the sensory evaluation (Sweetness, Crispness and Odour) and overall acceptability of banana springs by panellists

Banana spring	Time of frying	Sweetness	Crispness	Odour	Overall acceptability
Nangka	3	1.83[a]	3.67[d]	3.93[a]	2.83[b]
	4	1.83[a]	3.97[c]	4.13[a]	2.86[b]
	5	1.90[a]	4.37[b]	4.20[a]	4.63[a]
	6	2.17[a]	4.50[a]	4.27[a]	3.27[a]
Berangan	3	1.37[a]	3.80[a]	4.03[a]	2.37[b]
	4	1.40[a]	4.03[a]	4.07[a]	2.37[b]
	5	1.43[a]	4.43[b]	4.10[a]	2.93[a]
	6	1.57[a]	4.77[c]	4.27[a]	3.90[a]
Maximum		2.17	4.77	4.27	4.63
Minimum		1.40	3.67	3.93	2.37
Mean		1.687	3.817	4.125	3.145
SD		±0.89	±0.95	±0.92	±0.76

Values in columns having dissimilar letters indicate significant difference

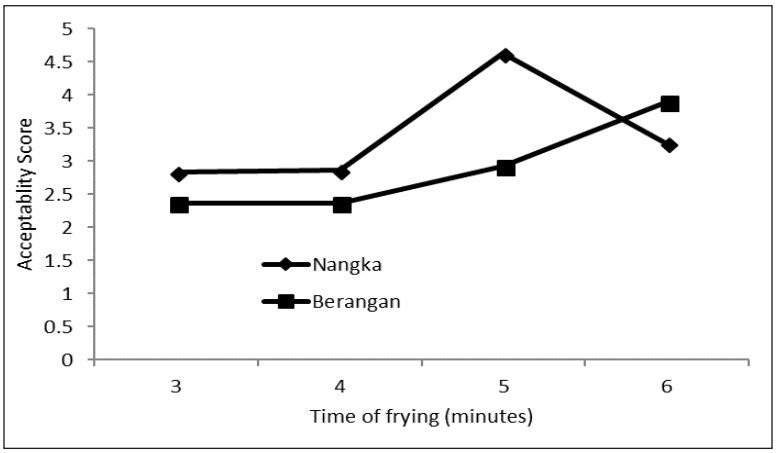


Figure 5. Effects of time of frying on overall acceptability of banana spring

(a) (b)

Figure 6. Fried banana springs of: (a) Berangan; and (b) Nangka varieties

CONCLUSION

The banana springs are a new addition to dried banana food products. Nangka banana at green matured stage can be used for making good quality banana springs. Frying the banana springs in a deep-fat fryer at 170°C for 5 minutes is enough to produce appropriate hardiness and crispness of the product. The observed acceptance score is support marketing prospects of banana springs in comparison to perishable raw fruit. Therefore, banana springs of both the varieties fried in a deep-fat-fryer at 170°C for 5 minutes may be promoted in food markets after comparing them with similar snack foods (e.g., potato chips, banana chips, etc.). This research also gives some impetus to study in-depth the physio-chemical properties of banana springs, effects of moisture content before frying, the shelf-life of banana springs under different packaging conditions, and effect of using crisping powder before frying to enhance the taste and quality of banana springs.

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