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Effect of Banana Ripeness and Puffing Temperature on Puffed Banana Qualities and Drying Time

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Abstract Puffing technique can improve textural quality of fat free crisp banana. In addition, the chemical composite of banana material influences on puffed product quality. The objective of this work was to study the effects of banana ripeness and puffing temperature on banana qualities such as colour, volume expansion and textural properties. The banana slices with 16-26°Brix of total soluble solids were blanched by hot water for 30 sec. After that, it was dried in 3 steps. First step, it was dried by hot air at temperature of 90°C until its moisture content reached 40% dry basis (d.b.). Then, it was puffed by hot air (130-170°C) for 2 min in a puffing machine. Final step, it was dried again by hot air at temperature of 90°C to moisture content of 4% d.b. The experimental results showed that higher degree of banana ripeness provided larger puffed volume but lower hardness of the product because lower amount of pectin content in banana tissue. However, as higher level of ripeness, more brown was found in puffed banana. In addition, higher puffing temperature induced larger puffed volume but lower hardness. The higher puffing temperature accelerated more browning in the puffed product than the other. To obtain a satisfied puffed banana product, the degree of banana ripeness should be reached at total soluble solid of 20-22°Brix and puffing temperature at 150°C.

Keywords: Banana Ripeness, Puffing, Texture, Colour, Snack.

Introduction

Banana is the economic fruit that harvesting throughout the year. However, its production yield exceeds market demand during some period time of the year causing spoilage. The drying process with hot air at a low temperature (70-90°C) is commonly applied to maintain the quality of bananas. Nevertheless, such dried banana was poor in quality such as high degree of shrinkage (Boualaphanh, 2007). The volume shrinkage is developed because water is removed from its cellular during drying process. The shrinkage of

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dried food is important quality because it affects product appearance and texture (Raikham *et al*., 2013; Zou *et al*., 2013) Several reports applied puffing technique combined with low temperature hot air drying to produce puffed product. Jayaraman *et al*. (1980) practically used puffing technique with plantain, carrots and potato. Varnalis *et al*. (2004) introduced hot air puffing to produce puffed potato. Tabtiang *et al*. (2016) also studied puffed banana using hot air or superheated steam. According to all reports, it was found that puffing technique combined with low temperature hot air (70-90 °C) could reduce degree of shrinkage of food stuffs because it was subjected to high temperature puffing medium, consequently, the moisture inside food material was so rapidly boiled and suddenly vaporized. This phenomena produced high vapor pressure that forces on the internal food structure to expand (Saca and Lozano 1992; Raikham *et al*., 2013). The larger volume after puffing step provided higher porosity inside puffed food, resulting in more crisp texture obtained from such structure characteristic (Tabtiang *et al*., 2012). Furthermore, the puffed product was less shrinkage and more crisp texture as it was puffed under higher level of puffing temperature, however, the puffed product color was deteriorated (Boualaphanh 2007). In previous researches, the ripeness degree of banana was fixed for producing of crisp banana slice. Tabtiang *et al*. (2012) studied puffed banana as its total soluble solid was in range of 23-21 °Brix. In addition, Raikham *et al.* (2013) produced puffed banana with fluidization puffing technique using banana ripeness at its total soluble solid in range of 18-16 °Brix. From previous studied, it was not clearly explained regarding influence of chemical composite of food material on puffing product quality.

As mentioned above, this research was therefore to study the effect of banana ripeness and puffing temperature on the quality of puffed banana qualities in terms of color, texture, shrinkage. In addition, the drying time of processing was also investigated.

Materials and methods

Banana preparation

Fresh Numwa-banana fruits were bought from local farm and their soluble solid contents were determined. They were divided according to total soluble solid contents into 3 groups as follows: 16-18, 20-22 and 24-26 °Brix. Before processing, the banana samples were cross sectional cut into 2.5 mm thickness and blanched by hot water at 95 °C for 30 sec. The blanching pretreatment provided more elastic of cellular that promoted volume expansion during puffing step (Varnalis *et al.*, 2004).

Puffing process

Banana processing of this study consisted of 3 drying steps. In first step, the banana slices were dried by hot air at temperature of 90°C under air velocity of 2 m/s. When the moisture content of banana samples reached 40% d.b., the samples were puffed by hot air at temperatures of 130, 150 and 170°C for 2 min. From preliminary test, the moisture content level was divided to 30, 40 and 50% d.b. The moisture content inside puffed banana at 40% d.b. provided largest volume expansion and lowest texture hardness of puffed product. In final step, the samples were dried again with hot air at temperature of 90°C until its final moisture content reached 4% d.b.

Volume expansion determination

The twenty banana samples were used to determine volume expansion. The volume of banana sample was determined by the solid displacement method using glass beads. The banana volume was calculated using following equation:

$$V = \frac{M_b - \left[M_{s+b} - M_v - M_s\right]}{\rho_b} \qquad (1)$$

where M_b is the mass of vessel filled with glass breads, M_v is mass of empty vessel, M_{s+b} is mass of vessel plus glass breads and banana sample, M_s is the mass of sample and ρ_b is the density of glass breads. The volume expansion of puffed banana was calculated from Eq. (2).

$$\text{\% volumetric expansion} = \frac{V}{V_i} \times 100 \qquad (2)$$

where V_i and V are the volume of the fresh sample and the volume of dried sample, respectively.

Colour evaluation

The twenty banana were used to evaluate colour. The colour of dried banana were measured using a colorimeter (ColourFlex, HunterLab, Buckinghamshire, UK). Before colour measurement the colorimeter was adjusted with standard white and black boards. The colour measurement was obtained by reflection and was made directly on puffed banana surface at six positions of which the average colour value was reported. The colour was expressed as L-value (Brightness), a-value (redness/greenness) and b-value (yellowness/blueness). The total colour change (ΔE) was calculated from Eq. (3)

$$\Delta E = \sqrt{(L - L_0)^2 + (a - a_0)^2 + (b - b_0)^2} \qquad (3)$$

where L_0 is the brightness of the fresh sample, L is the brightness of the dried sample, a_0 is the redness of the fresh sample, a is the redness of the dried sample, b_0 is the yellowness of the fresh sample and b is the yellowness of the dried sample.

Texture evaluation

The twenty banana samples were analyzed for their hardness using the texture analyzer (Stable Micro System, TA. XT. Plus, Haslemere, UK) with a 5 N load cell. The each banana sample was placed on plate base and it was fractured with a cutting probe (HDP-BSK type) at a speed of 2 m/s. The maximum compressive force from force deformation curve was considered as hardness.

Glucose, fructose and sucrose determinations

Analysis of sugar content in fresh banana was performed according to AOAC method 982.14 (1995). A 5 g banana sample was crushed and mixed with 50 mL distillated water. About 1.25 mL of 15% $K_4(Fe(CN_6))\bullet 3H_2O$ and 1.25 mL of 30% $ZnSO_4\bullet 7H_2O$ were added into the solution in order to extract the protein in banana sample. The liquid sample volume was adjusted by adding distilled water to 100 mL and filtered through No. 1 filter paper. Then, the filtered solution was filtered again through 0.2 µm syringe filter. The final volume of the filtered sample solution was kept in refrigerator until chromatographic analysis. Sugar content was analyzed by High Performance Liquid Chromatography (HPLC). About 10 µL of the filtered solution was injected into HPLC. Fructose, sucrose and glucose content in the banana could be separated by isocratic separation. Peak areas of samples were quantified with a standard curve.

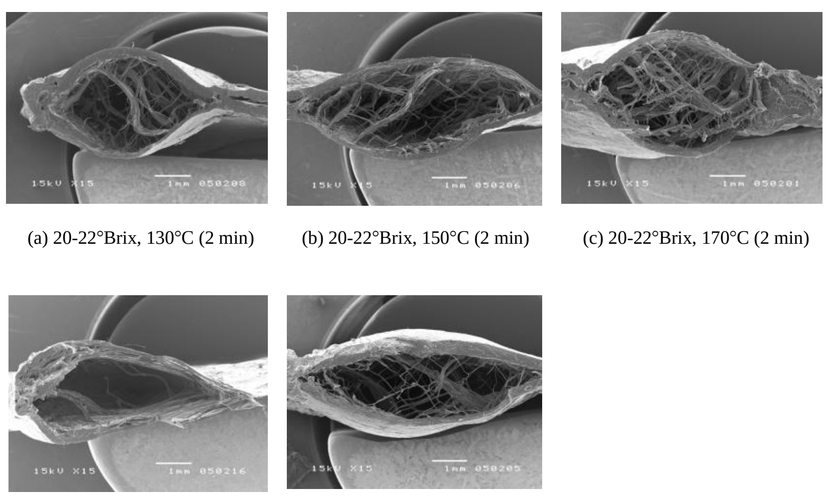
Statistical analysis

All experiments were performed in 3 replicated and the mean values with standard deviation were reported. The data of puffed product quality such as colour, volume expansion and texture were analyzed using analysis of variance (ANOVA), which indicated the effect of puffing condition on product quality. Turkey's test was used to establish the multiple comparisons of the mean values, which were considered significantly different when $p \leq 0.05$.

Results and Discussion

The morphological structure of puffed banana

Fig. 1 showed the morphology feature of puffed banana samples at various degree of ripeness and puffing temperatures. The morphology of all banana samples puffed with temperature in range of 130-170 °C had similarly appearance (Fig. 1 (a), (b) and (c)). It appeared large pores at internal area of puffed banana whilst the area nears the external surface was relatively dense. The produced large pore hinted the flash water evaporation during puffing step generating vapour pressure acting on the internal structure, resulting in expansion of cellular matrix (Varnalis *et al*. 2001). At a given temperature of 150 ºC, all puffed banana samples from different ripeness degrees, in Fig. 1 (b), (e) and (f), were similar.



(a) 20-22°Brix, 130°C (2 min) (b) 20-22°Brix, 150°C (2 min) (c) 20-22°Brix, 170°C (2 min)

(e) 16-18°Brix, 150°C (2 min) (f) 24-26°Brix, 150°C (2 min)

Figure 1. The morphology feature of puffed banana at various banana ripeness and puffing temperature levels.

Effect of banana ripeness and puffing temperature on volume expansion

Fig. 2 shows the effect of banana ripeness degree and puffing temperature on degree of volume expansion of banana. The puffing temperature significantly affected on volume expansion, the banana volume expansion increased as puffing temperature increased. This could be explained by the influence of higher amount of thermal energy transfers into food stuffs resulting in rapidly increasing banana temperature, as presented in Fig. 3. Consequently, the remained moisture available in banana sample quickly evaporated producing higher vapour pressure acting on internal food structure resulting in larger expansion of puffed banana (Mudahar *et al*. 1989; Tabtiang *et al*., 2012).

Considering the effect of banana ripeness degree, the lowest puffed banana volume was observed at 16-18°Brix at all puffing temperature levels. It is related with the amount of pectin, the 16-18 °Brix-banana sample had highest amount of pectin as showed in Table 1. Pectin is a major component of the middle lamella and it helps to bind cell together (Mohapatra *et al.,* 2010). Hence, higher amount of pectin contains in cellular provides stronger cell structure resulting in lower volume expansion during puffing step. In addition, the puffed volume significantly increased as the ripening was developed. This could be because the pectin inside banana tissue is degraded to monosaccharide as ripeness is developed.

Unexpected results occurred at ripeness of 24-26°Brix, the puffed sample is reversed to lower puffed volume, although the amount of pectin inside banana tissue had the lowest value. A possible explanation for this phenomenon may be that the lowest amount of starch content of 24-26°Brix-banana samples affected on volume expansion. Varnalis *et al*. (2001) proposed that the gelatinized starch layer that is generated during hot air drying of first stage processing could be escaped vapor during second processing stage of hot air puffing. Therefore, the escaped vapor potentially forces internal food structure to expand. Hence, the lowest amount of starch content of banana at 24-26°Brix of ripeness degree provided incomplete seal gelatinized starch layer after first stage drying. Consequently, the vapor easy leaked out from inside banana sample during puffing step.

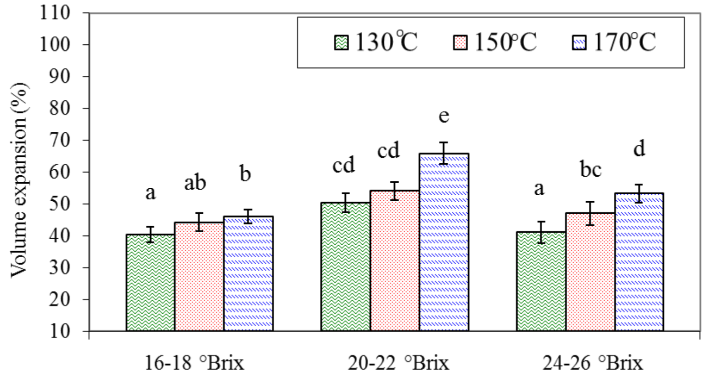


Figure 2. Effect of banana ripeness degree and puffing temperature on volume expansion**.**

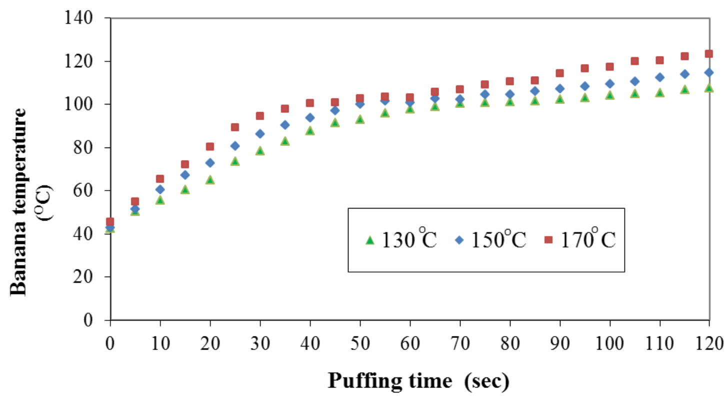


Figure 3. Temperature profile in banana sample during puffing at various puffing temperature levels.

Table 1. amount of starch, fructose, glucose and pectin content in fresh banana slices at various ripeness degrees.

Ripeness degree	Starch	Fructose	Glucose	Pectin
(°Brix)	(g/g dry mass)	(g/g dry mass)	(g/g dry mass)	(g/g dry mass)
16-18	1.03 ± 0.07^{c}	0.053 ± 0.006^{a}	0.051 ± 0.004^{a}	0.36 ± 0.05^{c}
20-22	0.71 ± 0.04^{b}	0.072 ± 0.010^{b}	0.071 ± 0.007^{b}	0.25 ± 0.03^{b}
24-26	0.52 ± 0.03^{a}	0.091 ± 0.008^{c}	0.094 ± 0.011^{c}	0.18 ± 0.04^{a}

* Different superscripts in the same column indicate a significant different at $p \leq 0.05$.

Effect of banana ripeness and puffing temperature on texture

The banana texture was presented in term of hardness as presented in Fig. 4. Increasing puffing temperature, puffed banana hardness decreased. However, the effect of puffing temperature was not significant on hardness ($p>0.05$) at 16-18°Brix of ripeness degree. A decrease in puffed banana hardness was associated with increasing puffed volume created under higher level of puffing temperature, as present in Fig. 2. Larger voids generated inside banana cell structure resulted in weaker texture as larger puffed volume (Tabtiang *et al*. 2016).

In addition, the ripeness degree linearly affected on puffed banana hardness. The highest hardness was observed at 16-18°Brix of ripeness degree. The hardness became lower as ripeness degree was developed. It is related with the amount of pectin, it is degraded at higher ripeness degree resulting in banana sample leading to softening texture (Mohapatra *et al*. 2010).

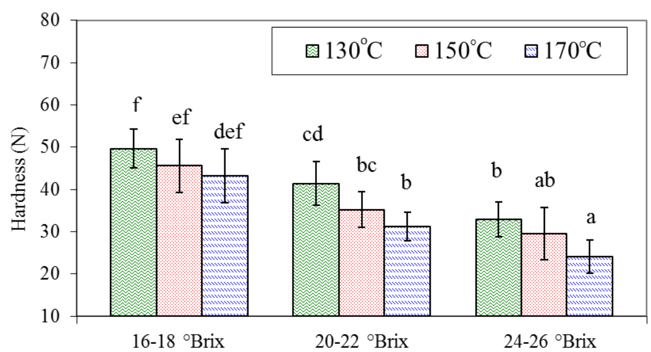


Figure 4. Effect of banana ripeness degree and puffing temperature on hardness.

Effect of banana ripeness and puffing temperature on colour

Fig. 5 shows the colour value of banana in term of ΔE at various puffing temperatures and banana ripeness degree. The puffing temperature directly affected on colour of puffed sample. Puffed samples were less brown as it were puffed under temperature of 130 °C. Increasing puffing temperature induced more brown colour on some areas of banana surface. Therefore, the ΔE value of puffed samples were increased as puffing temperature increased, as presented in Fig. 5. This could be described by the acceleration of non-enzymatic browning reaction at higher puffing temperature (Purlis 2010). However, puffing temperature insignificantly affected on product colour that prepared from banana at 16-18 °Brix. This may be due to the lowest amount of monosaccharide (glucose and fructose) at this ripening stage, as presented in Table 1.

Considering effect of ripeness degree on colour, the good colour of puffed product was obtained at 16-18 °Brix of ripeness degree. It had golden-yellow colour. However, the higher level of ripeness provided more scorching on surface and edge of samples. More browning intensity of banana sample as higher ripening degree indicated by higher ΔE value as presented in Figure 5. Degree of browning was related with the amount of monosaccharide in banana tissue (Tabtiang *et al*. 2016), as presented in Table 1.

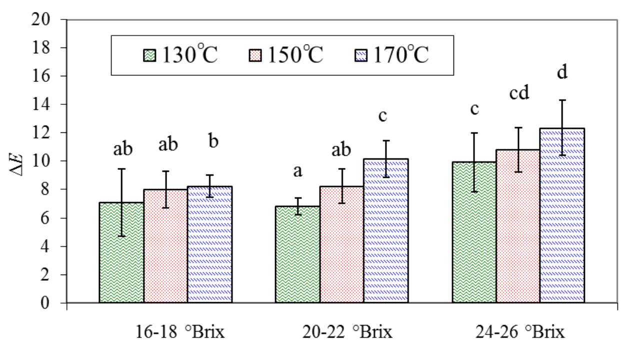


Figure 5. Effect of banana ripeness degree and puffing temperature on ΔE

Effect of banana ripeness and puffing temperature on drying time

The drying time of final drying stage is about 80-90% of total processing time, therefore this research mentioned on final drying stage. The finished drying process will consider the final moisture content of the dried banana slices was 4% d.b. Fig. 6 shows the effect of banana ripeness and puffing temperature on drying time of final drying stage. The puffing temperature strongly affected on drying time. At higher puffing temperature, drying time at all banana ripening levels could be reduced. The shorter total drying time undergoing such higher temperature is due to higher evaporation rate of moisture inside the banana sample. Thus, a shorter drying time was required in the final drying stage. Moreover, the higher puffing temperature allowed larger puffed volume creating higher porosity inside the puffed structure that facilitated rapid movement of moisture from inside to product surface (Louka and Allaf 2002; Prachayawarakorn *et al.* 2008).

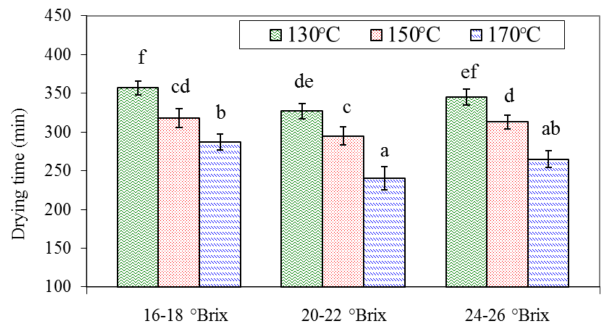


Figure 6. Effect of banana ripeness degree and puffing temperature on drying time of final drying stage.

In addition, the banana ripening degree affected on drying time of final drying stage. The puffed sample that prepared from banana at 20-22 °Brix required the shortest drying time at all puffing temperature levels. This could be due to the higher porosity inside food facilitating moisture movement in banana with a faster rate (Prachayawarakorn *et al.* 2008; Thuwapanichayanan *et al.* 2008). It should be noted that the drying times of puffed banana sample at other ripening degrees were not insignificantly different.

Conclusion

Ripening degree and puffing temperature strongly affected on puffed banana quality and drying time. Higher degree of ripening provided larger puffed volume and lower hardness. However, at higher ripening level, banana contains higher amount of monosaccharide resulting in more browning on puffed banana surface. Higher puffing temperature induced larger puffed volume and lower hardness but promoted more browning on puffed product. The optimum condition for producing puffed banana was found at ripening degree of 20-22 °Brix and puffing temperature of 150 °C.

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