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Effects of repeated frying and hydrocolloids on the oil absorption and acceptability of banana *(Musa acuminate)* fritters

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Abstract

The aim of this study was to determine the effects of xanthan gum and carrageenan on the oil uptake and acceptability of banana *(Musa acuminate)* fritters during repeated deep fat frying. Banana namely 'Pisang Awak' at maturity stage 6 were peeled, cut and dipped into 3 batter formulations containing 1% carrageenan, 1% xanthan gum and a control. The bananas were deep fried at 170±5°C for 3 minutes in 2.5L cooking oil without oil replenishment for 3 consecutive days. The moisture, oil content, texture, colour and acceptability of the banana fritters were evaluated at first and every 10th frying cycles. Results indicated that the oil and moisture content of fried bananas were dependent on frying cycles. The oil content increased while the moisture decreased with increased in frying cycles. There was significant reduction ($p<0.05$) in oil content of banana fritters dipped in batter containing xanthan gum compared to carrageenan and control. Fried bananas treated with xanthan gum also had significantly the highest moisture content. The hydrocolloids significantly increase the crust hardness even though there was no effect of repeated frying. The L^* value decreased with increased in frying cycle and 1% carrageenan treated fritters had the lowest value. Generally, banana fritter dipped in batter with 1% xanthan gum had the highest a^* while 1% carrageenan had the lowest b^* values. There was no significant different ($p>0.05$) in terms of overall acceptance between treated and untreated. Hence, 1% xanthan gum was effective in reducing oil absorption of banana fritters without affecting the overall sensory acceptability.

Introduction

Oil uptake is one of the most important quality parameters of fried food, which is incompatible with recent consumer trends towards healthier food and low fat food (Bouchon and Pyle, 2004). Despite the appealing characteristics of fried foods, the relatively high oil in the range of 33-38% is of concern due to its health reason as well as economic impacts (Al-Khusaibi and Niranjan, 2012). There have been many efforts to reduce oil absorption during deep fat frying using hydrocolloids of fried foods such as banana chips (Singthong and Thongkaew, 2009; Sothornvit, 2011), carrot slices (Akdeniz *et al*., 2006), chicken nuggets (Sahin *et al.*, 2005), fried battered squid ring (Sanz *et al*., 2004) and mashed potato balls (Mallikarjunan *et al.*, 1997).

Deep-fat frying is widely used in food preparation, which consists basically of immersion of food pieces into hot oil. During frying, interactions between oil and the product resulted in numerous physical, chemical and structural changes (Marquez *et al*., 2014). It involves two mass transfers in opposite directions within the food being fried: water and soluble materials escape from the core to the crust during frying and the water in the crust evaporates and moves out of the food, whereas oil penetrates the product (Gamonpilas *et al*., 2013).

Recently, many studies have been carried out with the aim of lowering oil uptake during deep fat frying. Brannan *et al.* (2013) reported that 1% of dried egg white and 2% of fiber solutions were successful in reducing oil content of chicken fritters. Gamonpilas *et al*. (2013) studied the effectiveness of various degree of cross-linked tapioca starches in batter to reduce oil uptake in fried chicken and revealed that substitution of 20% (w/w) cross-linked starches for wheat flour in the batter formulation significantly lower oil content by at least 17% relative oil reduction of fried chicken. Decreasing oil absorption during deep fat frying was also carried out by Rimac-Brncic *et al*. (2004) who reported reduction in oil content (27-28%) of potato strips blanched in calcium chloride solution.

Hydrocolloids have been widely used in numerous food and beverages products as thickener, gelling agent, stabiliser, emulsifier and controlling the rheology and texture of foods. Mellema (2003) reported surface modification by the hydrocolloid coatings can contribute to the reduction of the oil uptake during frying. Fiszman and Salvador

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(2003) indicated that the addition of hydrocolloids is generally effective at levels as low as 1% of the formulation dry weight or less, so that their addition does not dilute the functionality of protein in the flour base.

Asmita and Uday (2013) reported that the presence of 0.5% of CMC in chickpea and 1% of HPMC in green gram splits resulted in 28.65% and 15.24% reduction in oil content, respectively. Sakhale *et al.* (2011) proved that significant reduction in oil content in Samosa (8.56%) prepared with addition of xanthan gum at 1.5% level as compared to other hydrocolloids (HPMC, CMC, guar gum) and other concentration levels (0.5% and 1%). Singthong and Thongkaew (2009) investigated influence of hydrocolloid (pectin, carboxyl methylcellulose (CMC) and alginate) on the oil uptake of banana chips during frying and concluded that pectin was the most effective hydrocolloid for low fat fried banana chip production. The better oil barrier properties of methyl cellulose (MC) compared to hydroxypropyl methylcellulose (HPMC) had also been highlighted when applied to potato strips and dough disc in combination with sorbitol as plasticizer (Garcia *et al.*, 2002). In addition, a reduction in 23.1-54.8% oil content of fried battered squid ring was reported by Sanz *et al*. (2004) using 1-2% MC.

Banana *(Musa acuminate)* fritters is one of the most popular fried snack in Malaysia. However there was lack of information on banana *(Musa acuminate)* of Awak variety and to date no study has been carried out to reduce oil uptake in such product except for acrylamide content by Daniali *et al*. (2013). Hence, the objective of this study was to determine the effects of xanthan gum and carrageenan on the oil uptake, moisture, colour, texture and acceptability of banana fritters during repeated deep fat frying.

Materials and Methods

Materials

Banana *(Musa acuminate)* of Awak variety at maturity stage 6 (Jabatan Pertanian Malaysia, 2008) was purchased from a local market in Shah Alam, Selangor, Malaysia. Two types of food-grade hydrocolloids namely carrageenan and xanthan gum were purchased from Meilun Food Chemical Sdn. Bhd., Klang, Selangor, Malaysia. Rice flour (Erawan brand), salt (halagel brand), turmeric powder (Adabi brand) and cooking oil (Alif brand) were purchased from a local market.

Preparation of batters

The control batter was formulated using the method by Daniali *et al.* (2013) with a slight modification which consisted of rice flour (47.3%), sodium bicarbonate (1.5%), salt (1.0%), turmeric powder (0.2%) and water (50%). The hydrocolloids (carrageenan and xanthan gum) were added based on rice flour dry weight basis each at 1.0% level. The batter with hydrocolloids were formulated using the method by Xue and Ngadi (2009) with a slight modification where carrageenan and xanthan gum powder were first dispersed and mixed with 40% total amount of water while the other dry ingredients (rice flour, sodium bicarbonate, salt and turmeric powder) were mixed with remaining water. Then, the hydrocolloid solution was mixed thoroughly with the dry ingredients until a homogeneous batter obtained.

Frying protocols

Banana were peeled, cut and dipped into the batter. Using Bansal *et al.* (2010) method with minor modifications, an electric deep fat fryer (DFT-000, MSM, Malaysia) was filled with 2.5 L of cooking oil for every batch of frying. At the start of each day, oil was heated for 1 hour at 170±5°C. The temperature was measured using thermocouple. Then, the first frying cycle started. Subsequent frying cycles were performed at an interval of 30 min. During each frying cycle, 100 g of banana was deep-fried for 3 min. Ten frying cycles were performed every day. The oil was used continuously for 3 days without any replenishment. Each day, oil was heated for 6 hours and a total of 30 frying cycles were performed to each batch of oil. The banana fritters from the first and every ten frying cycles were allowed to cool and used for analysis of moisture, oil content, colour, hardness and sensory quality.

Moisture and oil content

The moisture content of banana fritters were measured using rapid moisture analyser (Ohaus MB45, USA) and the oil content was determined by Soxhlet apparatus (AOAC, 2002).

Colorimetric measurements

Banana fritters' colour was measured with a Minolta colorimeter (CR-400, USA) using the CIELAB colour parameters, L^*, a^* and b^*. A standard white calibration plate was used to calibrate the equipment.

Texture analysis

The crust crispiness of banana fritters was evaluated in terms of hardness by texture analyser (TA-XT2i Texture Analyser, Stable Micro System, England) using 5 kg load weight. The crust was separated from banana fritters and immediately attached to cylinder probe with a flat base 4 mm in diameter (Salvador *et al*., 2005).

Sensory evaluation

The banana fritters were evaluated for sensory quality attributes such as colour, appearance, crispiness, oiliness, taste and overall acceptability by 30 untrained panelists on 9 point Hedonic scale with 1 -extremely dislike and 9- extremely like.

Data evaluation

The experiment was conducted in three replications. The data generated during experimentation were analysed statistically by two-way Analysis of Variance (ANOVA). The level of significance was set at 5% using SAS version 9.1.

Results and Discussion

Oil content in banana fritters

Figure 1 depicts the oil content of banana fritters dipped in the three batter formulations. Oil content increased with increase in frying cycle for all samples. The high oil uptake with increase in frying cycle may be due to the increase in degradation products and viscosity of the frying medium as a result of thermal polymerization or oxidative deterioration during cooling (Blumenthal, 1991). There was no significance different ($p>0.05$) in oil content between control and banana fritters with 1% carrageenan at all frying cycles.

However, addition of 1% xanthan gum decreased the oil content significantly and resulted higher oil reduction compared to control (22.11%, 24.94%, 17.10% and 12.73% based on increase number of frying cycles, respectively). On the other hand, addition of 1% carrageenan gave less reduction in oil content with respect to control which were 1.24%, 1.07%, 1.21% and 1.00%. Hence, addition of 1% xanthan gum was more effective in reducing oil content of banana fritters compared to 1% carrageenan. This could be due to the higher viscosity of xanthan gum, which resulted in more weight gain to the banana fritters compared to carrageenan. This finding is in agreement with study by Sakhale *et al.* (2011) who reported that 1% xanthan gum in samosa had lower oil content (10.17%) than control formulation (18.34%).

The microstructure of the crust is the main determining factor for oil uptake which takes place by a capillary mechanism. Coating make the surface stronger and more brittle with fewer small voids which reduces evaporation and leads to less oil uptake and alter the water holding capacity by trapping moisture inside and preventing the replacement of water by oil (Singthong and Thongkaew, 2009).

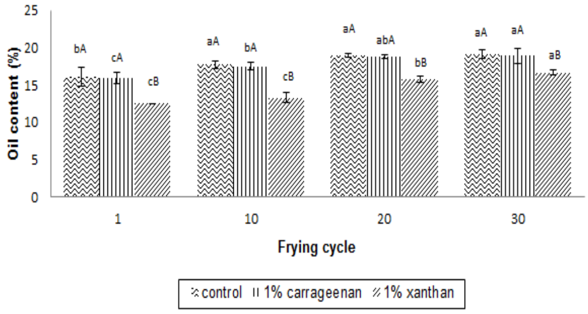

Figure 1. Oil content in banana fritters during repeated frying as affected by hydrocolloids
Means with different small letters are significantly different ($p<0.05$) between frying cycles in each formulation. Means with different capital letters are significantly different ($p<0.05$) between formulations.

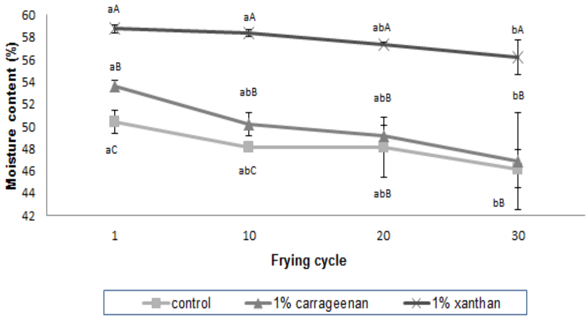

Figure 2. Moisture content of banana fritters during repeated frying as affected by hydrocolloids
Means with different small letters are significantly different ($p<0.05$) between frying cycles in each formulation. Means with different capital letters are significantly different ($p<0.05$) between formulations.

Moisture content in banana fritters

As shown in Figure 2, banana fritters treated with 1% xanthan gum had significantly higher moisture content ($p<0.05$) than control and those treated with 1% carrageenan at all frying cycles. The moisture content decreased with increase in frying cycles in all formulations.

Based on Figures 1 and 2, the higher the moisture content, the lower the oil content in banana fritters. This is due to oil absorption that occurred as moisture was removed from food during frying process (Salvador *et al*., 2008). The moisture content decreased after frying process due to removal of water by evaporation. Water starts evaporating as soon as the raw material is in contact with the oil (Yagua and Moreira, 2011). The drying rate was fast at initial and then slowed down as the product reach equilibrium.

Table 1. Colour properties of banana fritters during repeated frying as affected by hydrocolloids

Formulations	Frying cycles	Colour		
		L*	a*	b*
Control	1st	53.30±0.98^{aB}	10.67±1.6^{bA}	35.15±0.12^{aA}
	10th	50.64±1.19^{bA}	10.45±0.40^{bC}	32.45±1.30^{abA}
	20th	47.01+1.40^{cA}	14.79+0.54^{aB}	30.61+0.72^{bA}
	30th	43.14+0.28^{dA}	13.68+0.48^{aB}	27.49+1.59^{cA}
1% Carrageenan	1st	45.67±1.14^{aC}	13.83±0.54^{aC}	23.57±3.02^{bC}
	10th	43.66±0.89^{bB}	13.31±1.69^{aB}	28.08±1.99^{aB}
	20th	37.61+0.28^{cB}	14.54+1.77^{aB}	23.90+1.08^{bC}
	30th	34.19+1.02^{dB}	12.87+0.74^{aB}	17.22+0.93^{cB}
1% Xanthan gum	1st	58.41±1.13^{aA}	18.92±0.40^{bB}	28.19±0.15^{abB}
	10th	50.02+2.06^{bA}	20.77+0.14^{aA}	30.38+1.41^{aAB}
	20th	46.73+0.57^{cA}	19.61+0.70^{abA}	27.02+1.10^{bB}
	30th	42.81+1.32^{dA}	18.65+1.36^{bA}	25.86+1.79^{bA}

Note: L*=lightness; a*=red/green; b*=yellow/blue
Means with different small letters are significantly different (p<0.05) between frying cycles in each formulation. Means with different capital letters are significantly different (p<0.05) between formulations.

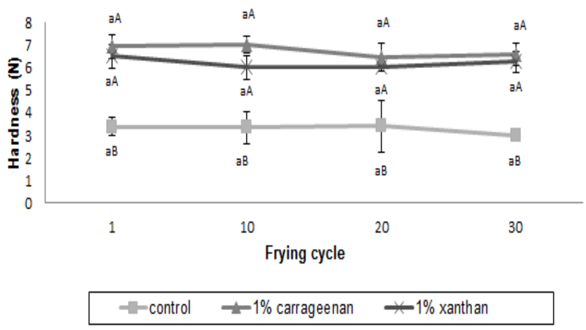

Figure 3. Hardness of banana fritters during repeated frying as affected by hydrocolloids

Means with different small letters are significantly different (p<0.05) between frying cycles in each formulation. Means with different capital letters are significantly different (p<0.05) between formulations.

Texture of banana coating

Texture is one of the important factors to determine the crispiness of the final fried food. The coating hardness of banana fritters was determined by the maximum peak force to penetrate the crust. The lower hardness indicates a more crispiness coating (Sothornvit, 2011). Figure 3 indicates there was no significance different in crispiness (hardness) with increase in frying cycles for all samples, but there was significant increase (p<0.05) in hardness of banana fritters treated with hydrocolloids. This result agreed with Salvador *et al*. (2005) who reported the addition of gum in the batter formulation had increase hardness of the coating due to the viscosity properties in the gum itself.

Colour of banana fritters

The *L** values of all samples decreased significantly (p<0.05) with increased in frying cycles, indicating darker fritters were obtained (Table 1). The increase in darkness of the fried samples could be due to changes in colour of the frying oil and Maillard reaction (carbohydrate/aldehydes react with amino-compounds) that took place during frying (Debnath *et al*., 2012). No significance different was observed between control and xanthan gum treated fritters. However, fritters treated with 1% carrageenan was significantly darkest (p<0.05) compared to others. The different in lightness between these two hydrocolloids may be due to reaction of different gum with batter and heat.

Generally, there was no significant changes in *a** value of the banana fritters during repeated frying (Table 1). However, the xanthan treated banana fritters are more reddish compared to others. For yellowness, the *b** value generally decreased with increased in frying cycle for all samples. The control sample exhibits significantly (p<0.05) more yellowish than hydrocolloid treated fritters.

Sensory evaluation of banana fritters

Table 2 shows no significance different (p>0.05) in the acceptance for crispiness, oiliness and taste between treated fritters and control. However, the panelists prefer appearance and colour of control sample than the treated banana fritters as the carrageenan resulted in darker colour and xanthan gum produced a more reddish fritters when measured instrumentally (Table 1). In terms of overall acceptability, the panelists like the carrageenan than the xanthan gum treated fritters and there was no significant different (p>0.05) between the treated fritters and the control.

Table 2. Sensory evaluation of banana fritters during repeated frying as affected by hydrocolloids using hedonic scale: 1 (dislike extremely) to 9 (like extremely)

Sensorial properties	Formulations	Frying cycles			
		1st	10th	20th	30th
Appearance	Control	7.07±0.94[a]	7.13±1.04[a]	7.27±1.11[a]	6.93±1.01[a]
	1% CG	6.50±1.7[ab]	6.47±1.66[ab]	6.23±1.59[b]	6.43±1.55[a]
	1% XG	5.93±1.66[b]	5.38±1.66[b]	6.23±1.48[b]	6.40±1.65[a]
Colour	Control	7.13±0.97[a]	7.23±1.07[a]	7.37±1.03[a]	7.37±1.03[a]
	1% CG	6.4±1.40[b]	6.57±1.43[ab]	6.20±1.45[b]	6.17±1.26[b]
	1% XG	6.07±1.60[b]	6.10±1.60[b]	6.20±1.40[b]	6.07±1.39[b]
Crispiness	Control	6.27±1.62[a]	6.27±1.62[a]	6.33±1.65[a]	6.67±1.45[a]
	1% CG	6.67±1.09[a]	6.87±1.25[a]	6.87±1.20[a]	7.17±1.39[a]
	1% XG	6.10±2.40[a]	6.10±2.34[a]	6.03±2.17[a]	6.97±1.54[a]
Oiliness	Control	6.67±0.80[a]	6.77±0.90[a]	6.87±0.94[a]	6.80±0.92[a]
	1% CG	6.40±1.13[a]	6.53±1.17[a]	6.50±1.22[a]	6.60±1.19[a]
	1% XG	6.57±1.36[a]	6.43±1.36[a]	6.47±1.25[a]	6.80±0.10[a]
Taste	Control	6.17±1.39[a]	6.30±1.37[a]	6.53±1.53[a]	6.37±1.47[a]
	1% CG	6.30±1.12[a]	6.40±1.19[a]	6.57±1.04[a]	6.37±1.13[a]
	1% XG	6.27±1.64[a]	6.17±1.58[a]	5.93±1.55[a]	6.57±1.77[a]
Overall	Control	6.57±1.10[a]	6.77±1.19[a]	6.83±1.18[ab]	6.87±1.00[ab]
	1% CG	6.73±0.87[a]	6.83±0.87[a]	6.93±0.98[a]	7.17±1.09[a]
	1% XG	6.40±1.45[a]	6.27±1.36[a]	6.27±1.36[b]	6.37±1.25[b]

CG: Carrageenan, XG: Xanthan gum
Mean with different small letters are significantly different ($p<0.05$) between formulations.

Conclusion

Repeated frying caused increased in oil absorption and darkness of banana fritters. The addition of 1% xanthan gum into batter significantly reduced oil absorption in banana fritters compared to control and 1% carrageenan. The frying cycles did not affect the texture but the addition of the two hydrocolloids increased the hardness. The xanthan gum and carragenaan influenced the colour of the fritters differently. There was no difference in terms of overall acceptability between control and treated fritters, but the carrageenan treated fritters was more acceptable than xanthan treated fritters. Further study on the effects of the hydrocolloids on the microstructure of banana fritters will be carried out.

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