Sains Malaysiana 47(11)(2018): 2699–2704
http://dx.doi.org/10.17576/jsm-2018-4711-13

Effect of Hydroxypropylmethyl Cellulose (HPMC) Coating on Flavour, Moisture and Oil Content in Chicken Nugget

(Kesan Salutan Selulosa (HPMC) Hidroksipropilmetil kepada Perisa, Lembapan dan Kandungan Minyak dalam Nuget Ayam)

LAI WENG HENG & MOHAMAD YUSOF MASKAT*

ABSTRACT

This study was carried out to determine the effects of hydroxy propyl methyl cellulose (HPMC) on the flavour compounds (eugenol and limonene), moisture and oil content in chicken nuggets during frying. Chicken nugget added with 500 ppm eugenol and limonene were coated with HPMC solution (0, 0.75 and 1.5%) and then with a commercial coating (ADABI, Malaysia). Chicken nuggets were fried at 180^{o}C for 4 min. Quantity of eugenol and limonene in the substrate (chicken meat) and coating were measured alongwith the moisture and oil content. The results showed that 0.75 and 1.5% HPMC were not able to retain either eugenol or limonene in both substrate and coating portion of the nuggets when compared to control except for eugenol in the substrate portion when using 1.5% HPMC. Application of HPMC also resulted in reduced moisture loss and oil absorption. The reduced moisture loss and oil absorption in the coating and substrate of the chicken nuggets showed that HPMC was able to form a barrier that restricted the migration of moisture from the nuggets and absorption of oil into the nuggets. However, only the 1.5% HPMC barrier formed was able to reduce the loss of eugenol in the nugget substrate. Both 0.75 and 1.5% HPMC was not able to significantly reduce the loss of limonene during frying.

Keywords: Chicken nugget; eugenol; frying; hydoroxypropyl methyl cellulose; limonene

ABSTRAK

Kajian ini dijalankan untuk menentukan kesan hidroksipropil metil selulosa (HPMC) terhadap kandungan bahan perisa (eugenol dan limonen), lembapan dan minyak di dalam nuget ayam semasa penggorengan. Nuget ayam dengan penambahan 500 ppm eugenol dan limonen disalut dengan larutan HPMC (0, 0.75 and 1.5%) dan kemudian dengan bahan penyalut komersil (ADABI. Malaysia). Nuget ayam digoreng pada 180°C selama 4 min. Kuantiti eugenol dan limonen di dalam substrat (daging ayam) dan salutan ditentukan berserta kandungan lembapan dan minyak. Keputusan menunjukkan 0.75 dan 1.5% HPMC tidak berkeupayaan mengekalkan kandungan sama ada eugenol atau limonen di dalam kedua-dua substrat dan salutan nuget apabila dibandingkan dengan kawalan melainkan eugenol di dalam substrat apabila menggunakan 1.5% HPMC. Penggunaan HPMC juga menghasilkan pengurangan kehilangan lembapan serta penyerapan minyak. Pengurangan kehilangan lembapan dan penyerapan minyak di dalam salutan dan substrat nuget ayam menunjukkan HPMC mampu untuk membentuk halangan yang menghalang perpindahan lembapan daripada nuget dan penyerapan minyak ke dalam nuget. Walau bagaimanapun, hanya halangan yang terbentuk daripada 1.5% HPMC mampu untuk mengurangkan kehilangan eugenol di dalam substrat nuget. Kedua-dua 0.75 dan 1.5% HPMC tidak mampu untuk secara ketara mengurangkan kehilangan limonen semasa penggorengan.

Kata kunci: Eugenol; hidroksi propil metil selulosa; limonen; nuget ayam; penggorengan

INTRODUCTION

Frying is a common cooking method in food processing due to its ability in producing food with good taste, crunchy texture and golden colour. It is a process where food is immersed in hot cooking oil, which allowed the interaction between oil, air and food to take place at temperature between 150°C and 190°C (Choe & Min 2007). Frying involves heat and mass transfer. Transfer of volatile substance through steam will take place during frying process. The loss of volatile components during frying is due to evaporation and decomposition reactions between volatile components with other food components (Choe & Min 2007). According to Li et al. (1993), frying causes high loss in blueberries flavour components that was added to food and the loss may reach up to 86%.

High starch foods like potatoes can be deep fried without any coating whereas coating is required for other foods to protect them from hot oil (Moreira et al. 1999). Coating improves the taste, appearance and texture of fried foods and reduces oil consumption due to the dry outer surface. Certain coating contains antioxidants, flavourings or oil consumption reducing agents such as hydrocolloid.

Nugget is one of the popular and favourite fried foods (Soorgi et al. 2011).

HPMC is a type of hydrocolloid which will turn into a gel when heated and returns to a liquid consistency when cooled. These properties allowed it to be used as a barrier in fried foods to reduce oil intake and moisture loss during frying. Addition of HPMC also helps to reduce the temperature and increase the viscosity which subsequently improves the formation and adhesiveness of dough (Chen et al. 2008).

Reduction of fried food quality can be attributed to, among other aspects, the migration of small molecules where the loss of aroma components reduces the intensity of flavour and change the original flavour of the food (Gennadios 2002). Establishing a barrier surrounding the product may reduce the loss of flavor compounds subsequently producing a better tasting fried product. HPMC, having a thermal gelation property may be suited for this purpose. Lim et al. (2009) reported on the ability of HPMC coatings to reduce the loss of eugenol in chicken nuggets during frying. However, the moisture and oil content was not reported. Thus, the objective of this study was to determine the effect of different concentration of HPMC coating on the content of two types of flavour (limonene and eugenol), along with the moisture and fat content of fried chicken nuggets.

Materials and Methods

Boneless and skinless chicken breast meat was used in this study. It was obtained from Gurney Chicken Sdn. Bhd., Bandar Sunway, Kuala Lumpur. The chicken meat was stored in a freezer at -18°C and thawed in the refrigerator at temperature of 4°C overnight before used. Hydroxypropylmethyl cellulose was purchased from Sigma (Perth, Australia). Eugenol and limonene solutions with 99% concentration was purchase form Merck (Germany). Flour was used as coating agent of chicken nugget in this study. ADABI flour (ADABI Consumer Sdn. Bhd., Selangor) was purchased from Pasaraya Bintang, Kajang. Pure palm oil (Vesawit, Yee Lee Edible Oil Sdn. Bhd.) was used as frying media in this study. Other ingredients that were used in this study was 1.25% (w/w) salt, 0.5% (w/w) sodium tripolyphosphate (STPP) and distilled water.

PREPARATION OF HPMC SOLUTION

HPMC solution was prepared based on the method presented in the study of Lim et al. (2009). For 0.75% HPMC solution, 0.75 g of HPMC powder was dissolved into 100 mL of distilled water. Temperature of distilled water was maintained at 45°C using hot plate and magnetic stirrer to facilitate the solvation of HPMC. For 1.5% HPMC solution, it was prepared by dissolving 1.5 g of HPMC powder in 100 mL of distilled water at 45°C. Temperature of the finished batter was at 45°C.

All HPMC solutions were left overnight to remove air that has been trapped during preparation. Before use, the HPMC solutions were inspected for visible air bubbles. After that, viscosity of HPMC solution was measured using a rotational viscometer (Model DV-II, Brookfield Engineering Laboratories, Stoughton, MA) equipped with a spindle. Each concentration of HPMC solution (80 mL) used a number 4 spindle drive and 20 rpm speed.

PREPARATION OF EUGENOL AND LIMONENE SOLUTIONS

Cooking oil was used as a solvent for the preparation of 0.05% (v/v) eugenol solution by mixing 0.025 mL of 99% eugenol with 50 mL cooking oil. After that, the mixture was homogenised for 5 min using vortex to ensure uniform mixing. The eugenol solutions were wrapped with a layer of aluminium due to its sensitivity towards sunlight. Similar steps were carried out to prepare the limonene solution.

PREPARATION OF CHICKEN NUGGET

Preparation of chicken nuggets were carried out according to Lim et al. (2009) with some modifications. Chicken meat, used as substrate, was cleaned and rinsed with water to remove excess fat and dirt. The meat was ground using a mill (Beem-gigant Type 5-6 Fleishwolf Starkey, Germany) until it turned into fine meat. Subsequently, the ground meat was mixed using a mixer (Hobart Model N-50, Machine serial no, 99-704-383-North York Ontario, Canada) for 30 s and mixed with 1.25% (w/w) salt and 0.5% (w/w) sodium tripolyphosphate for 2 min. Then, 0.05% of eugenol or limonene solution was added to the mixture and mixed for 1 min. Finally, chicken paste of 20 g per unit was weighed and moulded using a 5 × 5 × 5 cm mould.

Chicken nugget was coated based on the method of Lim et al. (2009). A commercial coating flour (ADABI Sdn Bhd) acted as coating material while HPMC solution or water acted as batter. Chicken nuggets were dipped into a container containing 85 g of HPMC solution. The dipped nuggets were taken out of the HPMC solution and placed in an 8 × 8 × 4 cm container in which 30 g of ADABI coating flour was placed. Three treatments were prepared which were Control (coated using water and ADABI coating flour only), 0.75% HPMC solution (coated with 0.75% w/w HPMC solution and followed by ADABI coating flour) and 1.5% HPMC solution (coated with 1.5% w/w HPMC solution and followed by ADABI coating flour).

FRYING PROCEDURE

Chicken nuggets were fried in hot oil bath at temperature of 180°C using GRAES Compact Fryer (GEKA, Germany) for 4 min. The nuggets were placed in a wire basket to drain off the excess oil and allowed to cool for 15 min. Coating of chicken nugget was separated from the meat using a knife. The meat without coating (substrate) was finely chopped and analysed.

ANALYSIS OF VOLATILE COMPOUNDS

Volatile compounds from the coating and substrate (chicken meat) samples of the fried chicken nuggets were extracted based on the method of Lim et al. (2009) using Solid Phase Micro Extraction (SPME). Chicken nugget coating and substrate samples (5 g each) before and after frying were inserted into vials and heated in a heating block (Block Digestor, Model-BD50, Malaysia) at a temperature of 53°C for 30 min. Extraction phase (stationary phase) of SPME consisted of polydimethylsiloxane cellulose fibre (PDMS). The fibre was exposed to the volatile compounds for 5 min. The fibre was then injected into a gas chromatograph for analysis.

Gas chromatography (Hewlett Packard Series III, Model 5890 second series) was used in this study to determine the quantity of eugenol and limonene compounds. Column used was HP% (Hawlett Packard Avondale, PA) with 30 m × 0.32 mm i.d. and filter with 0.2 µm thickness. 95% of Dimethyl-5% Diphenyl Polysiloxane was used as stationary phase where nitrogen gas was used as carrier gas. The column temperature was maintained at 180°C under isothermal conditions and the temperature of detector was set at 280°C. Quantification of the eugenol and limonene compounds were carried out based on a standard curve using eugenol and limonene solutions with 99% concentration (Merck, Germany).

DETERMINATION OF MOISTURE AND FAT CONTENT

Determination of moisture content was carried out according to AOAC (1995) using oven drying. Fat content of chicken nuggets was determined based on the Soxtec method (AOAC 1995).

STATISTICAL ANALYSIS

Statistical analyses were conducted using Statistical Analysis System (SAS) version 12.0. All data obtained in this study were in 3 replications and analysed using analysis of variance (ANOVA) while significant differences between the means were further analyzed using the Duncan test. A 95% confidence interval was used during the statistical tests.

RESULTS AND DISCUSSION

VISCOSITY OF HPMC SOLUTION

Table 1 shows the viscosity of HPMC solutions prepared using different concentrations. It was observed that an increase in HPMC concentration from 0.75 to 1.5 g/100 mL resulted in a significant (p<0.05) increase in viscosity. In general, HPMC is a type of hydrocolloid which is soluble in cold water and able to increase the viscosity of aqueous phase in food system. According to Amboon et al. (2012), HPMC is able to produce high viscosity solutions even when used at low concentration. Viscosity of hydrocolloid plays an important role in determining the final quality of the coating by influencing the amount of batter that can adhere on to the substrate during coating which indirectly affect the appearance and texture of the final product after frying. Therefore, viscosity of hydrocolloid may be the main factor in determining the nature of coating during frying (Varela & Fiszman 2011).

TABLE 1. Viscosity of HPMC solutions in different concentrations

Concentration of HPMC (g/100 mL water)	Viscosity (cps)
0.75	85.3±0.01[b]
1.5	913.9±0.01[a]

[a-b] Means with different letters are significantly different (p<0.05)

EUGENOL AND LIMONENE CONTENT

Table 2 shows the eugenol and limonene content of the substrate (chicken meat) portion of the nuggets before and after frying. The results showed frying samples at high temperature caused significant (p<0.05) loss in both eugenol and limonene from the uncoated and HPMC coated nugget substrate due to the flavor compounds' volatility. Heat supplied from the frying oil caused both eugenol and limonene to evaporate and migrate out of the substrate portion of the chicken nuggets.

Table 2 also shows that the use of 0.75 and 1.5% HPMC did not show any significant effect in maintaining limonene content compared to uncoated sample. Upon heating, HPMC was known to undergo gelation forming a layer of film which has barrier properties towards mass transfer (Amboon et al. 2012). This suggested that the barrier formed by HPMC upon thermal gelation was unable to prevent the loss of limonene from the substrate during frying. There was also no significant difference in limonene content between samples coated with 0.75% and 1.5% HPMC in the substrate portion of the chicken nuggets. This suggests that the increased HPMC concentration (1.5%) was also not able to serve as a barrier towards the migration and loss of limonene in the substrate portion during frying.

For eugenol samples, nuggets without HPMC coating retained 153.44 ppm or 39.32% of eugenol within the nugget substrate after frying. The use of 0.75% HPMC did not show a significant difference with uncoated sample while the use of 1.5% HPMC shows a significantly higher (p<0.05) retention at 91.61% or 357.45 ppm eugenol within the nugget substrate after frying. This indicated that use of 1.5% of HPMC significantly (p<0.05) reduced the loss of eugenol during frying in the substrate portion of the chicken nugget.

The higher retention of eugenol in 1.5% HPMC samples may be due to the barrier property of the HPMC coating. Barcenas and Rosell (2005) conducted a sensory study between bread with and without HPMC. The results showed that bread treated with HPMC gained higher acceptance in all quality aspects compared to control, including aroma and flavour of the bread.

The different effect by the HPMC treatment between limonene and eugenol was similar to the study conducted

TABLE 2. Flavour content in substrate portion (chicken meat) of nuggets coated with different concentration of hydroxy propyl methyl cellulose (HPMC)

Flavour compound	Flavour content (ppm)			
	Before frying	After frying		
	(without HPMC)	without HPMC	0.75% HPMC	1.50% HPMC
Limonene	467.42±0.01[a]	164.21±3.60[c]	178.85±0.01[c]	209.95±54.29[c]
Eugenol	390.19±0.01[a]	153.44±75.10[c]	163.70±74.06[c]	357.45±19.69[b]

[a-c] Means with different letters are significantly different (p<0.05)

by González-Tomás et al. (2004), where it was found that concentration of locust gum affected the aroma intensity of limonene but not the aroma intensity of isopentyl acetate. This suggests that hydrocolloids have different retention effects on different types of flavour compounds. It may also be due to the different boiling temperature between limonene and eugenol. Limonene has a boiling point of 177°C while eugenol has a boiling point of 252°C. In addition, the vapor pressure of limonene is 2.1 hPa at 20°C while the vapor pressure for eugenol is less than 0.1 hPa at 25°C (Anon 2018). The higher boiling point and lower vapor pressure of eugenol compared to limonene resulted in higher retainment of eugenol by the 1.5% HPMC samples.

Table 3 shows no significant effects (p>0.05) of the HPMC treatment in retaining the limonene and eugenol content in the nugget coating when compared to coating samples without the addition of HPMC. Similarly, the results in Table 3 shows no significant difference between 0.75 and 1.5% HPMC. Thus, the application of HPMC coating did not have any retention effect of limonene and eugenol in the coating during frying. The inability of the 1.5% HPMC coating samples to retain higher content of eugenol as observed for the substrate samples was due to the vicinity of the coating portion to the heat source (frying oil) compared to the substrate portion.

MOISTURE CONTENT

Table 4 shows the moisture content of substrate portion of nuggets coated with different concentration of hydroxy propyl methyl cellulose (HPMC) after frying. For limonene samples, moisture content of nugget substrate coated with HPMC was significantly higher (p<0.05) compared with control (68.14%). Similar results was obtained in the study conducted by Usawakesmanee et al. (2008). For eugenol samples, the use of HPMC significantly reduced (p<0.05) the loss of moisture content in the nugget substrate. In addition, increased HPMC concentration from 0.75 to 1.5% resulted in a significant increase (p<0.05) of moisture content in the substrate of the eugenol treated nuggets.

The ability of HPMC in reducing the loss of moisture content was due to the thermal gelation of HPMC. During heating, HPMC formed a layer of film, which acted as a barrier to prevent moisture loss (Amboon et al. 2012). The higher volatility of limonene as shown in its lower boiling point as discussed above could have facilitated the

TABLE 3. Flavour content in coating portion of nuggets coated with different concentration of hydroxy propyl methyl cellulose (HPMC) after frying

Flavour compound	Concentration of HPMC (%)		
	0.00	0.75	1.50
Limonene (ppm)	43.83±26.09[a]	27.59±4.18[a]	23.06±13.94[a]
Eugenol(ppm)	18.04±19.86[a]	16.43±18.53[a]	15.54±18.94[a]

[a] Means with the same letter are not significantly different (p>0.05)

TABLE 4. Moisture content in substrate portion of nuggets coated with different concentration of hydroxy propyl methyl cellulose (HPMC) after frying

Flavour	Concentration of HPMC (%)		
	0.00	0.75	1.50
Limonene	68.14±0.76[c]	74.83±0.04[b]	75.16±0.20[b]
Eugenol	65.57±0.23[d]	75.78±0.26[b]	77.41±0.46[a]

[a-d] Means with different letters are significantly different (p<0.05)

loss of moisture resulting in a significantly ($p<0.05$) lower moisture content in the limonene added substrate portion of the 1.5% HPMC coated samples compared to eugenol added samples.

Table 5 shows the moisture content of coating portion of nuggets coated with different concentration of hydroxy propyl methyl cellulose (HPMC) after frying. For limonene samples, moisture content of nugget coating was significantly higher ($p<0.05$) in control samples compared to HPMC coated samples. Meanwhile, only eugenol sample with 1.5% HPMC coating has a significantly lower ($p<0.05$) moisture content compared to eugenol control sample.

The formation of a barrier due to the gelation of HPMC may reduce the diffusion of moisture from the substrate to the coating (Chen et al. 2008) resulting in a lower moisture content in the coatings of HPMC coated samples. No significant differences were observed in moisture content of coating portion between limonene and eugenol added samples. This may be due to the effect of higher temperature caused by the vicinity of the coating portion to the frying oil which rendered the effect of different volatility between limonene and eugenol insignificant.

FAT CONTENT

From the result obtained (Table 6), the use of 0.75 and 1.5% HPMC resulted in a significant reduction ($p<0.05$) in fat content of the nugget substrate for both types of flavour. Reduction of oil absorption was due to the thermal gelation of HPMC which acted as a barrier to oil absorption (Chen & Moreira 1997; Usawakesmanee et al. 2008). Increase in HPMC concentration from 0.75 to 1.5% caused a significant reduction ($p<0.05$) in fat content between limonene samples while no significant difference ($p>0.05$) was observed between eugenol samples.

For control samples (0% HPMC), fat content of limonene sample was significantly higher ($p<0.05$) compared to eugenol. In addition, no significant differences were found between sample added with limonene and eugenol at a concentration of 0.75% HPMC while limonene sample has significantly lower ($p<0.05$) fat content compared to eugenol sample for 1.5% HPMC. These results suggested that different type of flavours resulted in a significantly ($p<0.05$) different effect on fat content of nugget substrate.

Primo-Martin et al. (2011) explained the mechanism of HPMC on controlling mass transfer is due to barrier formation caused by the thermogelation of HPMC where it physically reduces the migration of moisture from the product being fried and oil absorption during frying. As discussed previously, the difference in volatility between limonene and eugenol may have contributed to the significantly ($p<0.05$) lower fat content in the substrate portion of limonene added 1.5% HPMC coated nuggets which caused the generation of higher vapor pressure thus reducing the migration of fat into the nuggets.

Table 7 shows that fat content of nugget coating in limonene control sample was significantly higher ($p<0.05$) compared with limonene samples with HPMC coating. For eugenol sample, fat content in nugget coating of 0.75% and 1.5% HPMC coated sample was significantly lower ($p<0.05$) compared to control. Thus, the use of HPMC resulted in a reduction in oil absorption by nugget coating. This was due to the ability of HPMC in reducing the amount of oil being absorped during frying (Amboon et al. 2012). Increase in HPMC concentration from 0.75 to 1.5% significantly reduces ($p<0.05$) the fat content in the coating of limonene nugget while no significant difference ($p>0.05$) was observed between coatings of eugenol added nuggets.

There are no significant difference ($p>0.05$) in fat content of nugget coating between limonene and eugenol control sample (0% HPMC). At a concentration of 0.75 and 1.5% HPMC, fat content of the nugget coating in limonene sample was significantly lower ($p<0.05$) compared

TABLE 5. Moisture content in coating portion of nuggets coated with different concentration of hydroxy propyl methyl cellulose (HPMC) after frying

Flavour	Concentration of HPMC (%)		
	0.00	0.75	1.50
Limonene	46.26 ± 0.03^{a}	38.69 ± 0.55^{bc}	35.45 ± 0.08^{bc}
Eugenol	41.42 ± 1.50^{ab}	38.07 ± 3.00^{bc}	34.83 ± 4.60^{c}

$^{a\text{-}d}$ Means with different letters are significantly different ($p<0.05$)

TABLE 6. Fat content (d.b.) in substrate portion of nugget coated with different concentration of hydroxy propyl methyl cellulose (HPMC) after frying

Flavour	Concentration of HPMC (%)		
	0.00	0.75	1.50
Limonene	3.26 ± 0.04^{a}	1.93 ± 0.28^{c}	1.28 ± 0.08^{d}
Eugenol	2.61 ± 0.05^{b}	1.68 ± 0.11^{c}	2.00 ± 0.13^{c}

$^{a\text{-}d}$ Mean with different letter are significantly different ($p<0.05$)

TABLE 7. Fat content (d.b.) in coating portion of nugget coated with different concentration of hydroxy propyl methyl cellulose (HPMC) after frying

Flavour	Concentration of HPMC (%)		
	0.00	0.75	1.50
Limonene	23.18±1.23[a]	17.75±1.19[c]	14.69±0.25[d]
Eugenol	23.18±1.57[a]	21.69±0.18[ab]	19.77±0.57[bc]

[a-d] Mean with different letter are significantly different (p<0.05)

to eugenol. As discussed previously, the difference in volatility between limonene and eugenol may have contributed to the significantly (p<0.05) lower fat content in the coating portion of limonene added with 0.75 and 1.5% HPMC coated nuggets by slowing down the absorption of fat into the nuggets.

CONCLUSION

From the results, the reduced moisture loss and oil absorption in the coating and substrate of the chicken nuggets showed that HPMC was able to form a barrier that restricted the migration of moisture from the nuggets and absorption of oil into the nuggets. However, the HPMC barrier formed was only able to reduce the loss of eugenol in the nugget substrate only. HPMC was not able to significantly reduce the loss of limonene during frying.

REFERENCES

Amboon, W., Tulyathan, V. & Tattiyakul, J. 2012. Effect of hydroxypropyl methylcellulose on rheological properties, coating pickup, and oil content of rice flour-based batters. *Food and Bioprocess Technology* 5(2): 601-608.

Anonymous. 2018. *Product Safety Data Sheet*. www.merckmillipore.com.

AOAC. 1995. *Official Methods of Analysis*. 16th ed. Vol. 2. Method 935.29. Arlington, TX: Association of Official Analytical Chemists.

Bárcenas, M.E. & Rosell, C.M. 2005. Effect of HPMC addition on the microstructure, quality and aging of wheat bread. *Food Hydrocolloids* 19(6): 1037-1043.

Chen, Y. & Moreira, R.G. 1997. Modelling of a batch deep-fat frying process for tortilla chips. *Food and Bioproducts Processing* 75(3): 181-190.

Chen, C., Li, P., Hu, W., Lan, M., Chen, M. & Chen, H. 2008. Using HPMC to improve crust crispness in microwave-reheated battered mackerel nuggets: Water barrier effect of HPMC. *Food Hydrocolloids* 22(7): 1337-1344.

Choe, E. & Min, D.B. 2007. Chemistry of deep-fat frying oils. *Journal of Food Science* 72(5): 77-86.

Gennadios, A. 2002. *Protein-Based Films and Coatings*. Boca Raton: CRC Press.

González-Tomás, L., Carbonell, I. & Costell, E. 2004. Influence of type, concentration and flow behaviour of hydrocolloid solutions on aroma perception. *European Food Research and Technology* 218(3): 248-252.

Li, H.C., Risch, S.J. & Reineccius, G.A. 1993. Flavor formation during frying and subsequent losses during storage and microwave reheating in pancakes. In *Thermally Generated Flavors*, edited by Parliment, T.H., Morello, M.J. & McGorrin, R.J. Washington: American Chemical Society. 543: 466-475.

Lim, M.F., Maskat, M.Y. & Wan Mustapha, W.A. 2009. Kesan hidroksipropil metil selulosa dan jangka masa penggorengan terhadap kehilangan eugenol semasa penggorengan. *Sains Malaysiana* 38(3): 347-351.

Moreira, R.G., Castell-Pérez, M.E. & Barrufet, M.A. 1999. *Deep Fat Frying: Fundamentals And Applications*. Gaithersburg, Md: Aspen.

Primo-Martín, C., Sanz, T., Steringa, D.W., Salvador, A., Fiszman, S.M. & Van Vliet, T. 2011. Performance of cellulose derivatives in deep-fried battered snacks: Oil barrier and crispy properties. *Food Hydrocolloids* 24(8): 702-708.

Soorgi, M., Mohebbi, M., Mousavi, S.M. & Shahidi, F. 2011. The effect of methylcellulose, temperature, and microwave pretreatment on kinetic of mass transfer during deep fat frying of chicken nuggets. *Food and Bioprocess Technology* 5(5): 1521-1530.

Usawakesmanee, W., Chinnan, M.S., Wuttijumnong, P., Jangchud, A. & Raksakulthai, N. 2008. Effect of edible coating ingredients incorporated into predusting mix on moisture content, fat content and consumer acceptability of fried breaded product. *Songklanakarin Journal of Science and Technology* 30(1): 25-34.

Varela, P. & Fiszman, S.M. 2011. Hydrocolloids in fried foods. A review. *Food Hydrocolloids* 25(8): 1801-1812.

Faculty of Science & Technology
Universiti Kebangsaan Malaysia
43600 UKM Bangi, Selangor Darul Ehsan
Malaysia

*Corresponding author; email: yusofm@ukm.edu.my

Received: 30 March 2018
Accepted: 23 July 2018