

The Effects of Edible Coating Ingredient as a Barrier to Moisture and Fat of Fried Breaded Potato

Worapong Usawakesmanee¹, Phaisan Wuttijumnon², Manjeet S. Chinnan³,
Anuvat Jangchud² and Nongnuch Raksakulthai⁴

ABSTRACT

The effects of edible coating material and their concentrations on viscosity of coating solutions, moisture and fat contents of fried breaded potato were investigated. Viscosity of chitosan (CH), hydroxypropyl methylcellulose (HPMC) and wheat gluten (WG) were measured using Brookfield viscometer with small sample adapter. The results showed a good correlation between the log viscosity values and edible coating concentrations for all treatment combinations ($R^2 > 0.94$). The viscosity of CH, HPMC and WG coating solutions varied from 66.3-918.0 cp, 43.7-932.3 cp and 134.0-773.3 cp, respectively. Viscosity value in the middle range was selected for coating blanched potatoes. Samples were first coated with the edible solutions and followed by sequentially predested, battered, breaded and fried at 170°C for 3 min. Moisture and fat content in the core, crust and intact of samples were determined. Moisture content in the crust portion of samples coated with HPMC (18.9%) was significantly higher than the uncoated (14.8%) while the fat content of all samples was not significantly different. Increasing the viscosity of HPMC reduced the moisture loss and fat absorption more effectively than CH and WG. Adding 9% of HPMC edible ingredient into predesting mix produced a breaded potato with higher moisture and lower in fat.

Key words: edible films, deep fat frying, potato, moisture content, fat content

INTRODUCTION

Deep fat frying foods play an important role in food preparation, especially in convenient foods. Fried foods constitute a primary choice in the diets and have remained ever popular among today's consumers of all ages. Because of changes in life style of consumers in term of preparation and consumption of food needed to spend less time, the relative importance of fried foods has escalated into the restaurants, fast food joints and

supermarkets as ready-to-eat or easy-to-prepare entrées for immediate consumption. In general, fried battered and breaded products are either battered (puff-tempura) or battered and breaded (interface-adhesion) prior to deep fat frying (Loewe, 1993). They can be classified base on the substrate that is being coated such as, meat, fish and vegetables (Brandt, 2002). Batter used for fried foods can be defined as liquid dough, basically consisting of flours, starches, seasoning and water. Batters have become more sophisticated complex

¹ Department of Food Technology, Prince of Songkla University, Songkla 90112. Thailand.

² Department of Product Development, Kasetsart University, Bangkok 10900. Thailand.

³ Department of Food Science and Technology, University of Georgia, Griffin, GA 30223-1797 USA.

⁴ Department of Fishery Products, Kasetsart University, Bangkok 10900. Thailand.

systems in which the nature of the ingredients is very wide ranging and their interaction affects the finished product (Fiszman and Salvador, 2003). There are some studies showing the basic ingredients that contribute better covering characteristics and final texture of fried products (Baixauli *et al.*, 2003; Salvador *et al.*, 2002). Frying lends several enticing characteristics including appearance, aroma, flavor and texture (crispness), however, the quantity of oil in fried food has increased after frying. Since consumers are concerned about the health risks associated with fat consumption and low fat foods, there is a need for reducing oil absorption in fried products. Lowering the overall fat content without adversely altering the crispy outer layer and softer inner texture will enhance the appeal of fried foods (Hunter, 1991; Varela, 1988). One approach would be to use an edible film ingredient that will improve the coating performance and serve as a shield to control the diffusion of moisture and fat in battered and breading products. Various types of edible coating and film have been reported on the application in fried food, including gelatine, gellan gum, k-carrageenan-konjac-blend, locust bean gum, microcrystalline cellulose, pectin, sodium caseinate, soy protein isolate, wheat gluten, whey protein isolate (Albert and Mittal, 2002) methylcellulose (Albert and Mittal, 2002; Holownia *et al.*, 2000; Mallikarjunan *et al.*, 1997), corn zein (Mallikarjunan *et al.*, 1997), hydroxypropyl methylcellulose (Balasubramaniam *et al.*, 1997; Holownia *et al.*, 2000; Mallikarjunan *et al.*, 1997). However, it is difficult to compare their relative efficiencies in terms of barrier properties to moisture and fat of fried products. It is necessary to find a criteria for the selection of edible coatings in food applications.

The application of edible coating and film has been carried out on a direct coating to product surface as reported by Albert and Mittal (2002), Balasubramaniam *et al.* (1997). The common application methods were dipping, spraying or

casting. Material was coated or wrapped with film prior to the further process. On the other hand, several studies have done on the effect of adding edible ingredients into a batter formulation (Sanz *et al.*, 2004; Holownia *et al.*, 2000). However, limited research work has demonstrated the use of edible coating ingredients incorporating into predesting mix.

The objectives of this study were 1) to determine the viscosity of coating solutions from chitosan (CH), hydroxypropyl methylcellulose (HPMC) and wheat gluten (WG) in order to establish a criteria for the selection of coating concentration. 2) to evaluate barrier property of coating ingredients by mean of direct coating and incorporating into predesting mix in battered and breaded potatoes.

MATERIALS AND METHODS

Materials

Experiments were conducted using three types of coating ingredient namely chitosan (CH), hydroxypropyl methylcellulose (HPMC) and wheat gluten (WG). CH (low molecular weight, minimum 75-85% deacetylated) and polyethylene glycol were purchased from Aldrich Chemical Company, Inc. (Milwaukee, WI, USA). HPMC, food grade E4M was provided by The Dow Chemical Company (Midland, MI, USA). WG (approx. 80% protein) was obtained from Sigma-Aldrich Company (St. Louis, MO, USA). Battering and breading ingredients include wheat flour, corn flour, rice flour, sugar, salt, garlic powder, ground white pepper and bread crumb were purchased from the local grocery store. Modified starches used in predest and batter formulation (Batterbind S™, Crispfilm™ and Crisp Coat UC™) were obtained from the National Starch and Chemical Company (Bridgewater, NJ, USA).

Preparation of edible coating solutions

CH solutions at different concentrations

(0.9, 1.2, 1.5, 1.8 and 2.1% w/v) were prepared using the modified method of Rhim *et al.* (1998). The CH powder was dispersed in deionized water while stirring on a magnetic stirrer for 15 min. Acetic acid was added to obtain 1% concentration in the coating solutions. Each solution was stirred at room temperature for 1 hour and filtrated through cheesecloth to remove undissolved impurities. After filtration, the solution was mixed with polyethylene glycol (0.25 ml/g CH) and ethanol and further stirred for 15 min.

HPMC solutions at different concentrations (0.6, 0.8, 1.0, 1.2 and 1.4 % w/v) were prepared according to the manufacturer's direction given in "A Food Technologist's Guide to Methocel® Food Grade Gums" (Dow, 1999). The HPMC powder was dispersed initially into hot water (80-90°C), equalling to one fifth of the total volume, followed by adding ice cold water while continuously agitating the solution to rapidly cool below 30°C. Then absolute ethanol was added to achieve 0%, 15% and 30% concentrations.

WG solutions at different concentrations (4, 5, 6, 7 and 8% w/v) were prepared using the modified method of Gennadios *et al.* (1993). WG powder was dispersed into a mixture of ethanol and glycerol solution heating on a magnetic stirrer/hot plate followed by slowly incorporating deionized water to the film solution. The pH of

solution was adjusted to 4.0 by using 50% (v/v) acetic acid solution. The formulations of edible coating solution used in this study are shown in Table 1.

Viscosity measurement

The viscosity of the solutions was measured at room temperature with a Brookfield Digital Viscometer (model LVTD, Brookfield Engineering Laboratories, Inc., Middleboro, MA, USA) using a small sample adapter (spindle No. SC4-18/13R, sample volume 8 ml, shear rate 3.96/s). The edible coating solutions were stirred for 5 min by using an agitator and degassed in a vacuum oven at 8.45 kPa for 30 min before measuring.

Predust and batter preparation

The basic predusting mix consisted of 1:2:1 (wheat flour : Batterbind S™ : Crispfilm™) by weight. The ingredients were mixed and sifted five times in order to obtain the uniform distribution of the mixer.

Batter formulation consisted of wheat flour (40%), Batterbind S™ (18%), Crisp film™ (12%), Crisp Coat UC™ (10%), corn flour (6%), rice flour (3%), sugar (4%), salt (4%), garlic powder (1.5%) and ground white pepper (1.5%). The batter was prepared by blending the dry ingredients with refrigerated deionized water (5°C) using a Hobart

Table 1 Formulations of edible coating solution.

Film type	Base ingredient (g)	Water (ml)	Acetic acid (ml)	Plasticizer (ml)	Ethanol
CH*	0.9, 1.2, 1.5, 1.8, 2.1	66.4-97.9	1	PEG* 0.25 ml/g CH	0, 15, 30
HPMC*	0.6, 0.8, 1.0, 1.2, 1.4	68.6-99.4	-	-	0, 15, 30
WG*	4.0, 5.0, 6.0, 7.0, 8.0	38.8-64.4	-	Gly* 40% of WG	30, 40, 50

*Note: CH = chitosan, HPMC = hydroxypropyl methylcellulose, WG = wheat gluten, Gly = glycerol, PEG = polyethylene glycol

mixer (Hobart Manufacturing Co., Troy, OH, USA) at speed 1 for 3 min. The ratio of dry mix to water was 1:1.1 (w/w).

Coating and frying protocol

Russet potatoes were obtained from a local grocery store. The potatoes were washed and cut into cylindrical shapes ($\varnothing = 1$ cm, $L = 5$ cm) using a cork borer and soaked in cold tap water until ready to be blanched in hot water at 85°C for 6 min (Khalil, 1999). Each batch was cooled with iced water and drained for 5 and 3 min, respectively. The batches were combined for uniformity, and stored at -18°C before frying.

Prior to the application of edible coatings, the samples were thawed overnight at 5°C and surface dried with paper towels for good adhesion. They were then dipped into the coating solution for 30 s and dried under an electric fan (ambient temp, 5 m/s). The coated samples were predested with 8% (of sample weight) predesting mix, battered with batter mix and breaded with bread crumb. After battering and breading, samples were fried in vegetable oil, using a deep fat fryer (Wells Auto Fryer, Wells Manufacturing Co., San Francisco, CA, USA) at 170°C for 3 min. All fried samples were drained for 1 min and allowed to cool down to ambient temperature on paper towels for 20 min.

The application of edible coating incorporated into predesting mix

HPMC and WG were chosen to incorporate into predesting mix because CH was insoluble in water. The amounts of 3, 6, 9 and 12% HPMC or WG were mixed with the basic predesting mix and sifted five times each to obtain the uniform homogeneous mixture. The basic predesting mix without adding HPMC or WG was used as control. The samples were coated with 8% predesting mix, battered, breaded and then fried. All fried samples were drained and cooled down in the same manner as the edible film coating.

Moisture and fat determination

Fried samples were gently handled to separate the crust from core and stored in sample bags. Moisture and fat content of the fried samples were measured for the ground crust, core and intact. Moisture content was determined as the weight loss of sample after drying by a freeze dryer (Virtis Genesis 25 ES Freeze dryer, Virtis Company, Gardiner, NY, USA). The fat content of freeze dried samples was determined using supercritical fluid extraction (Suprex Fatmaster GA, Isco Inc., Lincoln, NB, USA). The samples were extracted with supercritical CO₂. The extraction vessel was a 5 ml stainless steel vessel. Supercritical fluid extraction was conducted at pressure of 450 atm and temperature of 95°C for the duration of 30 min dynamic, and 9 min static. CO₂ flow rate was set at 3.2 ml/min.

Statistical analysis

The regression analysis was performed to obtain the best fit between the log of viscosity and concentration. General Linear Model was used to test the effects of edible coating on the product's moisture and fat content. Duncan's Multiple Range Test was applied to estimate the significant differences among the means at 95% confidence levels (SAS, 1989).

RESULTS AND DISCUSSION

Effects of concentration and ethanol on viscosity of edible coating solution

CH solution was clear pale yellow color. The viscosities of CH solution increased with increasing CH concentration and ethanol level. Viscosities of CH solutions containing 0%, 15% and 30% ethanol were 66.3-712.7 cP, 96.6-719.0 cP and 126.7-918.0 cP, respectively.

HPMC solution was clear and colorless. The viscosities of HPMC solution increased with increasing HPMC concentration and ethanol level. Viscosities of HPMC solutions containing 0%,

15% and 30% ethanol were 43.7-727.7 cP, 64.0-664.0 cP and 96.3-932.3 cP, respectively.

WG solution was opaque pale yellow color. The viscosities of WG solution also increased with increasing WG concentration and ethanol level. Viscosities of WG solution containing 30%, 40% and 50% ethanol were 134.0-514.7 cP, 154.3-666.0 cP and 171.7-773.3 cP, respectively.

The relationship between log viscosity and concentration of all coating solutions showed linear regression with R^2 values greater than 0.94 (Figure 1). The coating solutions almost fell in the same range of log viscosities of 2.22-2.67 (Figure 2). Therefore, the viscosity at the middle range (2.45) was chosen for determination of the concentration of coating solution from the regression equations. The concentrations of CH without ethanol (CH), CH with 15% ethanol (CH 15), CH with 30 % ethanol (CH30), HPMC without ethanol (HPMC), HPMC with 15% ethanol (HPMC 15), HPMC with 30 % ethanol (HPMC 30), WG with 30% ethanol (WG 30), WG with 40% ethanol (WG 40) and WG with 50% ethanol (WG 50) were 1.59, 1.37, 1.25, 1.11, 0.97, 0.87, 6.39, 5.64 and 5.36%, respectively. These concentrations were used for preparing coating solutions.

Effects of edible coating on moisture and fat content

The effects of edible coating on moisture and fat content of battered and breaded potato are shown in Figure 3. The moisture content of treated and control core portion, crust layer and intact fried samples ranged from 68.0 to 69.7%, 13.2 to 18.9% and 43.6 to 46.7%, respectively. The HPMC coating produced a significant increase in moisture content of crust and intact. A similar trend was observed by Mallikarjunan *et al.* (1997) working with potato balls and found the moisture content of coated surface layer was significant higher than those of uncoated samples. However, these results were contrast to the result obtained by Holownia *et al.* (2000) that the moisture content of coated crust

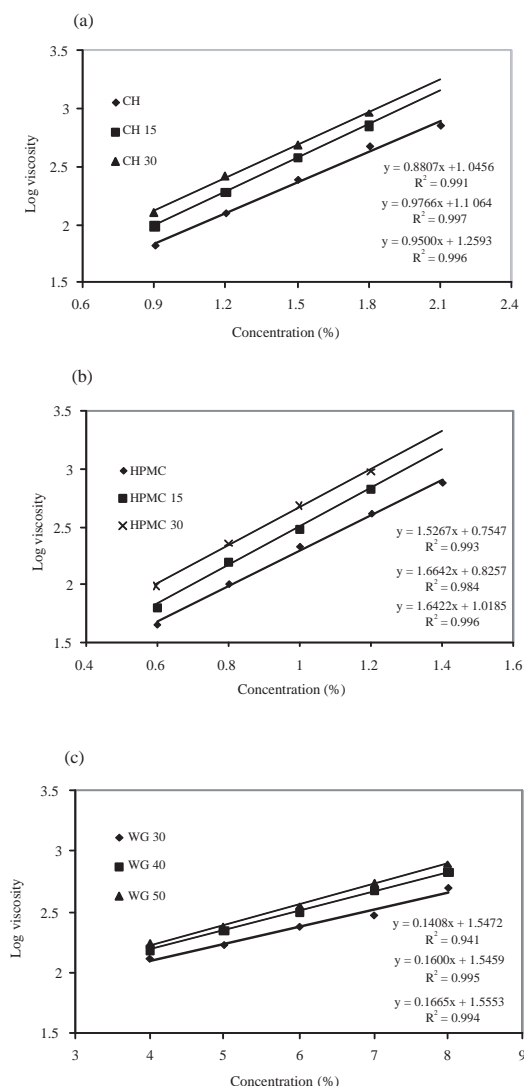
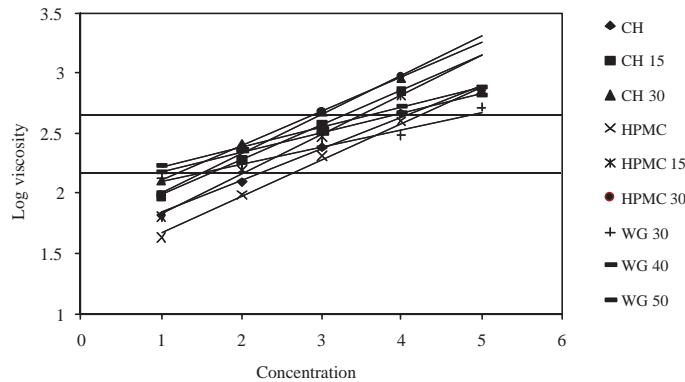


Figure 1 Linear relationship between concentrations and log viscosity of CH (a), HPMC (b) and WG (c) coating solutions; CH = chitosan, CH 15 = chitosan with 15% ethanol, CH30 = chitosan with 30 % ethanol, HPMC = hydroxypropyl methylcellulose, HPMC15 = hydroxypropyl methylcellulose with 15% ethanol, HPMC30 = hydroxypropyl methylcellulose with 30% ethanol, WG 30 = wheat gluten with 30 % ethanol, WG 40 = wheat gluten with 40 % ethanol, WG 50 = wheat gluten with 50 % ethanol.



CH 1=0.9%, 2=1.2%, 3=1.5%, 4=1.8%, 5=2.1%

HPMC 1=0.6%, 2=0.8%, 3=1.0%, 4=1.2%, 5=1.4%

WG 1=4.0%, 2=5.0%, 3=6.0%, 4=7.0%, 5=8.0%

Figure 2 The similar viscosity ranges exhibited from CH, HPMC and WG coating solutions; CH = chitosan, CH 15 = chitosan with 15% ethanol, CH 30 = chitosan with 30 % ethanol, HPMC = hydroxypropyl methylcellulose, HPMC 15= hydroxypropyl methylcellulose with 15% ethanol, HPMC 30=hydroxypropyl methylcellulose with 30% ethanol, WG 30= wheat gluten with 30 % ethanol, WG 40 = wheat gluten with 40 % ethanol, WG 50 = wheat gluten with 50 % ethanol.

in HPMC coated fried marinated chicken strips was lower. The increase in moisture content of HPMC coated sample might be due to the rehydration of the coated film during battering and penetration of moisture to the crust during frying process.

Although the differences in moisture content found between the control and treated sample were significant, the differences in fat content were not significant. The fat content of core portion, crust portion and intact in treated and control samples varied from 21.4 to 22.9%, 27.6 to 29.6% and 25.3 to 26.9%, respectively.

The selected coating viscosity seems not to be an effective barrier to control the moisture and fat migration. This could be due to coating concentrations and type of ingredient. Albert and Mittal (2002) reported that gluten film (12.5%) was not suitable for fried foods, samples coated with gluten film formed huge bubbles during frying, samples looked like small balloons and oil entered

inside the bubbles. In the study carried out by Wu *et al.* (2000), they used CH coating (2%) as a barrier to control moisture loss and lipid oxidation in precooked beef patties and found that CH coating reduced the moisture loss but not effective in controlling lipid oxidation. Comparison to this study, the CH film might not resist the water pressure during frying resulting in non-significant effect on moisture and fat content.

Effects of increasing edible coating viscosity on moisture and fat content

This investigation was conducted using CH, HPMC and WG with 30% ethanol at the log viscosity of 3.0 (1,000 cP). The concentrations calculated from the equation were 2.22, 1.47 and 10.32%, respectively. The application of edible coating and frying were conducted at the same fashion as previous study. Increasing viscosity of HPMC solution produced a significant reduction in fat content of core, crust and intact, and increase

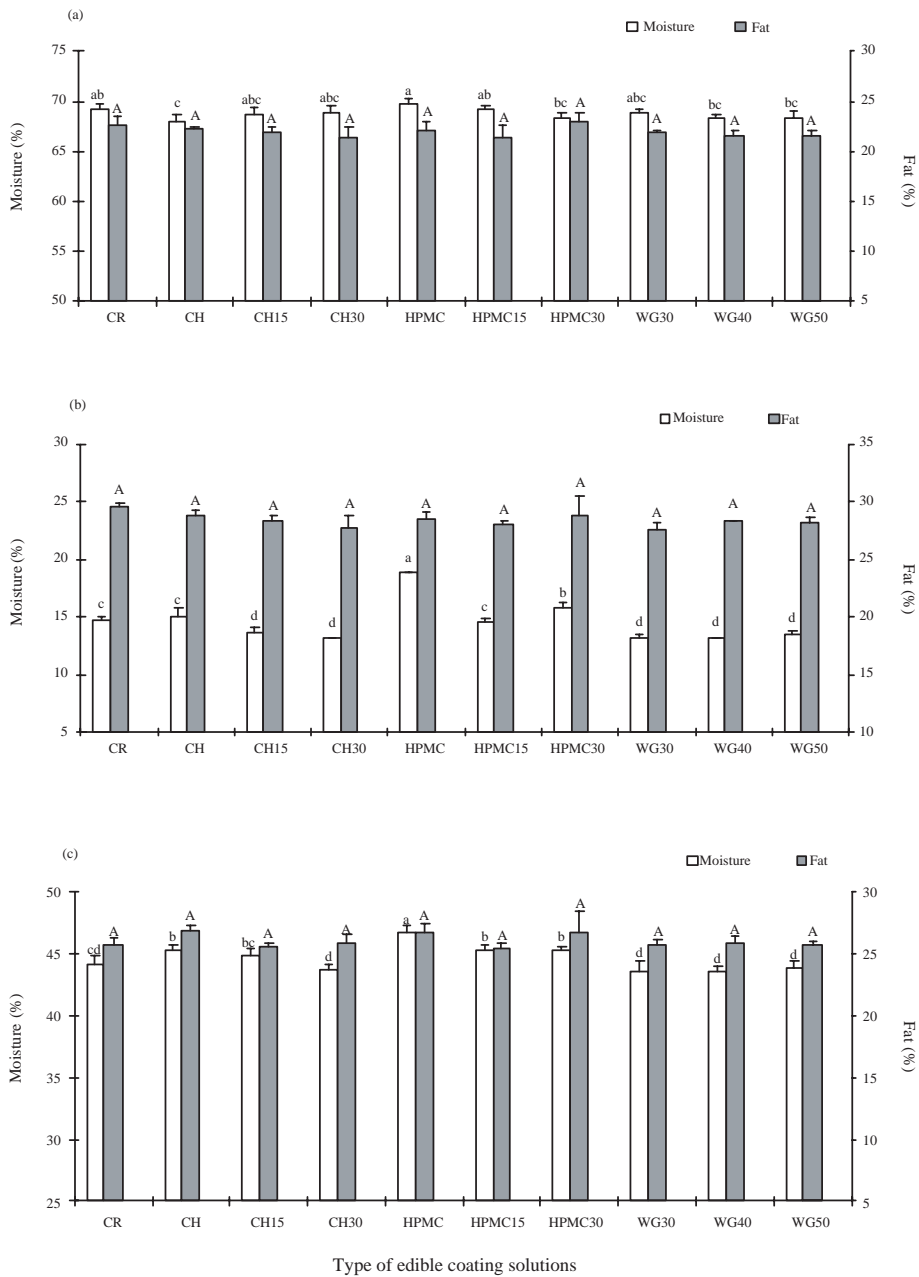


Figure 3 Moisture and fat content of battered and breaded potato coated with different coating solutions at the concentration of 2.45 log; core (a), crust (b) and intact (c); For each moisture and fat value, bars with different letters are significantly different ($p \leq 0.05$); CR = control, CH = chitosan, CH 15 = chitosan with 15% ethanol, CH 30 = chitosan with 30 % ethanol, HPMC = hydroxypropyl methylcellulose, HPMC 15= hydroxypropyl methylcellulose with 15% ethanol, HPMC 30=hydroxypropyl methylcellulose with 30% ethanol, WG 30= wheat gluten with 30 % ethanol, WG 40 = wheat gluten with 40 % ethanol, WG 50 = wheat gluten with 50 % ethanol.

in moisture content of crust (Figure 4). The moisture contents of crust in comparison with the control were $17.5 \pm 0.7\%$, and $14.7 \pm 1.3\%$. However, the differences in moisture and fat content found between CH, WG coated samples and the control were not significant.

The approach of using higher viscosity may be an alternative way to determine the barrier efficiency of these coating solutions. A limitation for coating application is drying time. Coating solution with high viscosity may need more time for the film forming on the product surface because of increasing in amount of film mass deposited onto the substrate.

Effects of edible coating ingredient incorporated into predusting mix on moisture and fat content

The effects of edible coating ingredient incorporated into predusting mix using HPMC and WG were investigated. Figure 5 shows the moisture and fat contents of core, crust and intact as affected by the concentrations of HPMC and WG. The effectiveness of incorporating HPMC and WG into predusting mix as moisture and fat barrier in comparison with the control could be clearly seen. The HPMC concentration up to 9% produced a significant reduction in fat absorption and increase in moisture retention in the core portion. WG concentrations up to 6% produced only a significantly increase in moisture retention in the core portion (Figure 5a). This indicated that WG had no effect on reduction in fat absorption in core portion. There were slightly higher fat content in the crust portion of HPMC treated samples and slightly lower moisture content in the crust portion of WG treated samples than in the control (Figure 5b). The 9, 12% HPMC and 9% WG treated samples retained more moisture and absorbed less oil than the control (Figure 5c).

These results showed that HPMC incorporated into predusting mix was more effective than WG in moisture loss and fat absorption reduction. Similarly, Ang (1993)

reported that the fat contents of fried batter coating were reduced and the moisture contents increased when 1% powdered cellulose with fiber size greater than 100 μm incorporated into batter. The application of edible film ingredient incorporated into predusting mix showed the favorable properties as compared with using direct film coating on the product surface or incorporating into batter. The advantage of this application is it can be easily introduced into the production process and has proven to be beneficial to both the food industry and consumers.

CONCLUSIONS

Viscosity of CH, HPMC and WG solutions were affected by concentrations of the coating ingredient and ethanol content. CH, HPMC and WG concentrations were calculated from regression equation at the middle of viscosity range (2.22-2.67 log). The HPMC coating gave higher moisture content of the crust portion, while no differences in fat content of core portion, crust portion and intact between treated and control samples. Increasing the HPMC viscosity resulted in the reduction of crust moisture loss and fat absorption in breaded potato. Incorporating 9% HPMC into predusting mix was the best barrier to control the moisture and fat migration.

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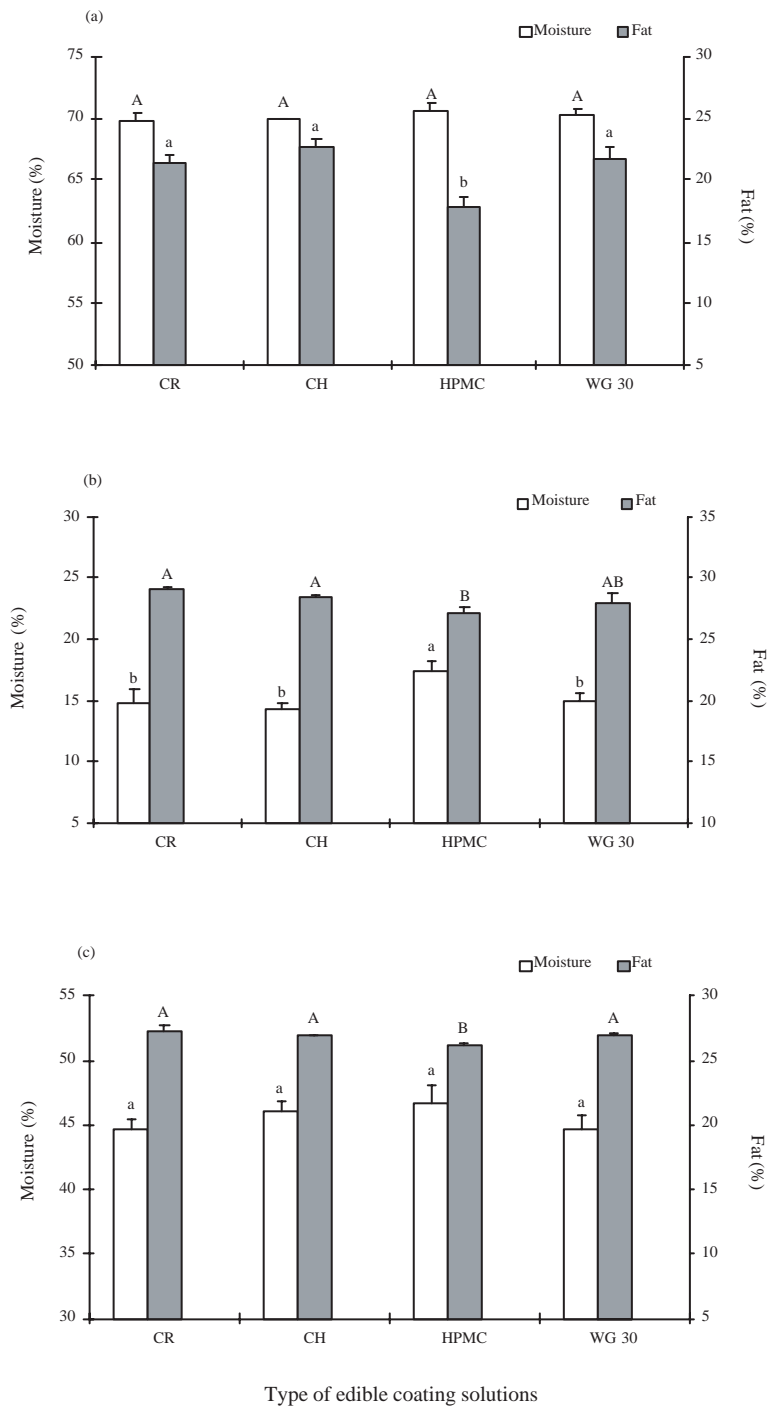


Figure 4 Moisture and fat content of battered and breaded potato coated with different coating solutions at the concentration of 3.0 log; core (a), crust (b) and intact (c); For each moisture and fat value, bars with different letters are significantly different ($p \leq 0.05$); CR = control, CH = chitosan, HPMC = hydroxypropyl methylcellulose, WG 30 = wheat gluten with 30% ethanol.

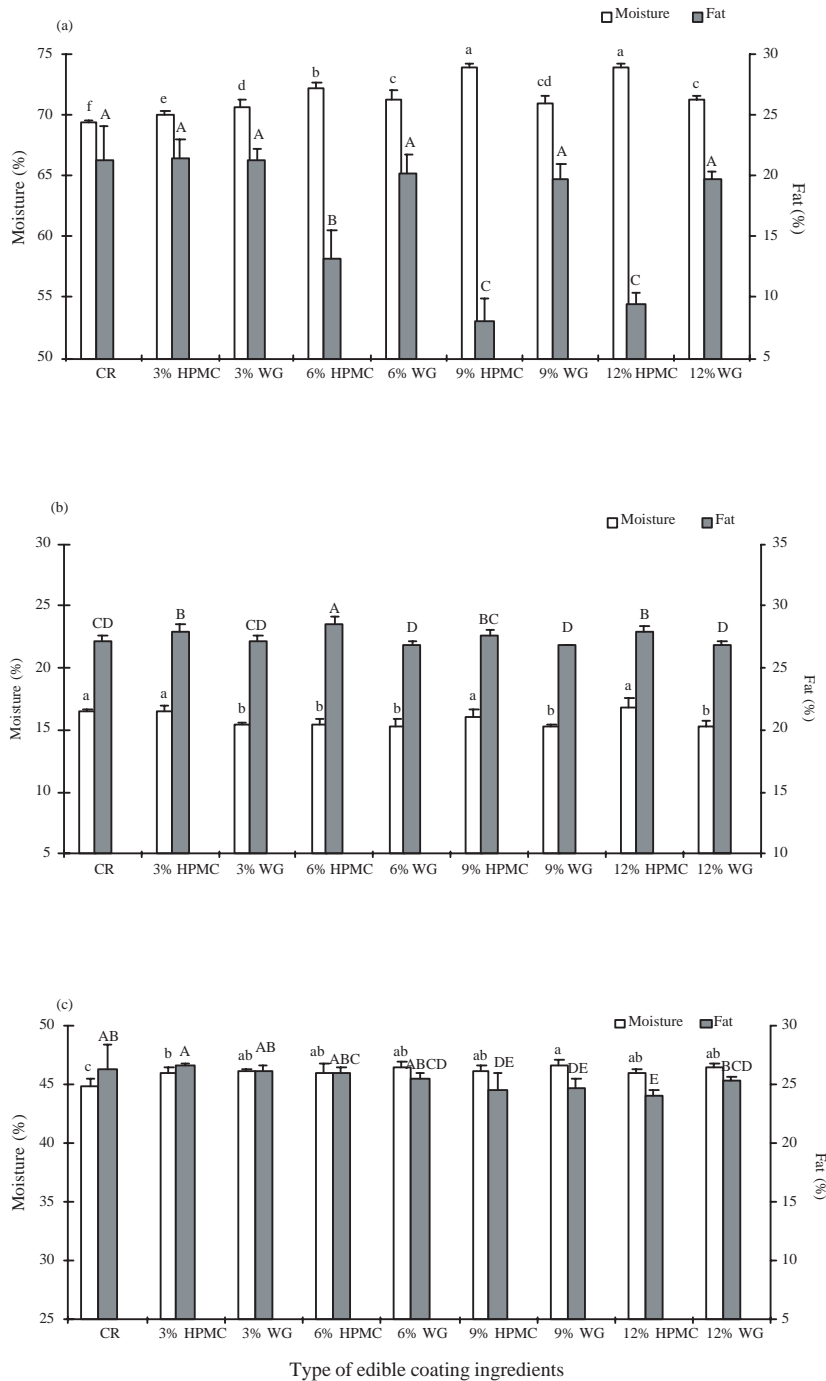


Figure 5 Effects of edible coating ingredient incorporated into predusting mix on the moisture and fat content of fried potato; core (a), crust (b) and intact (c); For each moisture and fat value, bars with different letters are significantly different ($p \leq 0.05$); CR = control, 3-12% HPMC = 3-12% of hydroxypropyl methylcellulose incorporated into predusting mix, 3-12% WG = 3-12% of wheat gluten incorporated into predusting mix.

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