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Original Article

Effect of edible coating ingredients incorporated into predusting mix on moisture content, fat content and consumer acceptability of fried breaded product

Worapong Usawakesmanee[1]*, Manjeet S. Chinnan[2], Phaisan Wuttijumnong[3], Anuvat Jangchud[4], and Nongnuch Raksakulthai[5]

[1] *Department of Food Technology, Faculty of Agro-Industry, Prince of Songkla University, Hat Yai, Songkhla, 90112 Thailand.*

[2] *Department of Food Science and Technology, University of Georgia, Griffin, GA , 30223-1797 USA.*

[3] *Department of Agro Industrial Management Technology, Faculty of Agro-Industry, Prince of Songkla University, Hat Yai, Songkhla, 90112 Thailand.*

[4] *Department of Product Development, Faculty of Agro-Industry,*

[5] *Department of Fishery Products, Faculty of Fisheries, Kasetsart University, Chatuchak, Bangkok, 10900 Thailand.*

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Abstract

The effect of edible coatings and their concentrations on moisture and fat contents of fried breaded potato were investigated. Hydroxypropyl methylcellulose (HPMC), methylcellulose (MC) or wheat gluten (WG) were incorporate into predusting mix to achieve coating material concentration of 3-12% (w/w). Blanched potatoes were first coated with predusting mix and followed sequentially by battering, breading and deep frying at 170°C for 3 min. Moisture and fat contents in the core and crust of sample and intact samples were determined. It was found that HPMC and MC could reduce moisture loss and fat absorption than WG. Predusting mix with 6% MC was the most effective to retain moisture and reduce fat absorption. This predusting mix was then applied to commercial breaded shrimps. In both prefried and fried products, treated breaded shrimps had more moisture and less fat than untreated breaded shrimps. They also were lower in product hardness and crust hardness than untreated samples. Sensory evaluation showed that treated and untreated shrimp samples had similar rating for appearance, color, flavor, taste, texture and overall. Treated breaded shrimp was acceptable to the consumers. The application of edible coatings into predusting mix can be easily introduced into the production process and is beneficial to both food industry and consumers.

Keywords: edible coating, deep fat frying, moisture content, fat content, breaded shrimp

1. Introduction

Deep fat frying foods play an important role in food preparation, especially in convenience foods. Fried foods constitute a primary choice in our diets and have remained ever popular among today's consumers of all ages. Because of changes in lifestyle of consumers in terms of preparation and consumption of food that requires little 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

*Corresponding author.
Email address: worapong.u@psu.ac.th

to deep fat frying (Loewe, 1993). They can be classified based 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 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 coatings and films 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) and hydroxypropyl methylcellulose (Balasubramaniam *et al.*, 1997; Holownia *et al.*, 2000; Mallikarjunan *et al.*, 1997). 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) and 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 been done on the effect of adding edible ingredients into a batter formulation (Sanz *et al.*, 2004a; Holownia *et al.*, 2000). However, limited research work has demonstrated the use of edible coating ingredients incorporated into predusting mix.

The objectives of this study were 1) to evaluate barrier property of coating ingredients i.e. hydroxypropyl methylcellulose (HPMC), methylcellulose (MC) and wheat gluten (WG) incorporated into predusting mix in battered and breaded potatoes, and 2) to investigate the effect of edible coating ingredient on textural properties and sensory acceptability of the product.

2. Materials and Methods

The experiments were conducted using three types of coating ingredients: hydroxypropyl methylcellulose (HPMC), methylcellulose (MC), and wheat gluten (WG). HPMC, food grade E4M and MC, food grade A4M were 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 predust and batter formulation (Batterbind S™, Crispfilm™ and Crisp Coat UC™) were obtained from the National Starch and Chemical Company (Bridgewater, NJ, USA).

2.1 The use of edible coating ingredient in breaded potato

Basic predusting mix consisted of wheat flour, Batterbind S™ and Crispfilm™ (1:2:1 w/w/w). The dry ingredients were weighed, combined and sifted several times for the uniformity. HPMC, MC and WG were incorporated into the basic predusting mix by adding 3, 6, 9 and 12% (w/w) of each coating ingredient to basic predusting mix. Each treatment was mixed and sifted five times in order to obtain a uniform distribution of edible coatings. The basic predusting mix without adding HPMC, MC or WG was used as control. 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 mixer (Hobart Manufacturing Co., Troy, OH, USA) at speed 1 for 3 min. The weight ratio of dry mix to water was 1:1.1.

The samples were predusted with 8% (w/w) of predusting mix, battered with viscous batter and breaded with bread crumb. After battering and breading, samples were fried in soybean oil (Golden Chef™, ADM Packaged, Decatur, IL, USA), using a deep fat fryer (Wells Auto Fryer, Wells Manufacturing Co., San Francisco, CA, USA) set 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.

Moisture content of the fried samples was measured separately for the core, crust and intact portions. Moisture content was determined as the weight loss of sample after drying using a freeze dryer (Virtis Freeze dryer, Virtis Company, Gardiner, NY, USA). The fat content of freeze dried samples was determined using a Labconco Goldfisch Fat and Oil Extractor (Labconco Corp., Kansas City, MO, USA) for the extraction period of 24 h and petroleum ether was used as the extraction solvent (AOAC, 1999). The texture analyses were assessed based on the barrier properties of coatings to reduce moisture loss and fat absorption. The most promising treatment was selected to compare with the control sample. The treated intact samples were prepared and fried in the same manner as mention previously. The texture analysis was performed by the compression method with ten blades Kramer Shear Cell using Instron Universal Material Testing System (Instron model 5500 R, Instron Corporation, Canton, MA, USA). The crosshead speed of the instrument was set at 100 mm/min. The data on maximum force (hardness) and area up to the maximum peak force was recorded and calculated by the Merlin® software. The most promising coating condition was also applied to the commercial breaded shrimp.

2.2 The application of edible coating ingredient in commercial breaded shrimp

Fresh white shrimp (*Litopenaeus vannamei*) were used as a food matrix for the coating application. Shrimp were washed, beheaded and peeled while leaving the tail portion on. The shrimp were deveined and washed in cold water and drained for a minute. The shrimps were then individually frozen with liquid CO_2 using spiral belt freezer and stored at -18°C until used. Commercial predusting mix (Code PP-003) was used as the base ingredient and mixed with MC at 6% (w/w) concentration. The mixtures were mixed and sifted five times in order to ensure a uniform distribution of film ingredient. The viscous batter was prepared from the commercial batter mix (Code PB-001). The batter powders were mixed with cold water using a mixer. The weight ratio of dry mix to water was 1:1.2. After preparation, the batter was poured into a tray which was cooled with ice under the tray. The frozen shrimps were first dipped in water for 5 s, and then predusted with predusting powder (with and without edible film ingredient). The dust pickup was controlled at approximately 10% of shrimp weight. The shrimps were immersed in batter for 5 s and allowed to drip for 5 s. The battered shrimps were breaded with breaded crumb (Code WD2-12) and kept in a chilled room (4°C) until frying. The breaded shrimps were prefried for 1.5 min in vegetable oil in a continuous belt fryer at 180°C. The prefried product was frozen using liquid CO_2 in the spiral belt freezer for 20 min. The breaded shrimps were packed in a plastic bag. The frozen samples were transported in styrofoam box to the Department of Food Technology, Prince of Songkla University, and stored at -18°C until the physicochemical analyses, sensory evaluation and consumer acceptance test were conducted.

Moisture and fat analyses were performed on prefried as well as final fried breaded samples. The prefried samples were thawed in chilled room at 4°C for 12 h. The samples were separated into core portion, crust portion and intact. Each sample was ground with the grinder (Moulinette model 327, Spain). Moisture content was determined as the weight lost of samples after drying using freeze dryer (Dura Top/ Dura Dry MP, FTS Systems™, Stone Ridge, NY, USA). The dried samples used for moisture content determination were subsequently extracted with petroleum ether in a Soxhlet apparatus during a period of 14 h (AOAC, 1999).

For the final fried samples, the prefried samples were fried in soybean oil at 170°C for 3 min. The samples were cooled for 20 min at ambient temperature. The samples were separated into core portion, crust portion and intact. Each sample was ground with the grinder. Moisture and fat contents were determined as described above.

The texture measurement of final fried treated and control breaded shrimp was made using a texture analyzer (TA. XT2i, Stable Micro System, Godalming, Surey, UK) interfaced with a data process texture expert version 1.17. The samples were fried in soybean oil at 170°C for 3 min and drained for 1 min. The fried samples were cooled for 20 min at ambient temperature. The texture measurements are described below.

Kramer shear test: Two pieces of edible portion of breaded shrimp were placed across the bottom of a five blade Kramer shear cell. Blades were driven downward at the speed of 2 mm/s and using 25 kg load cell. The peak force (firmness) and area up to the peak force from the force deformation curve were obtained. Six replications were analyzed for each sample. Puncture test: A cylindrical flat end punch (2 mm diameter probe) was used. The operating parameter consisted of a test speed of 1.7 mm/s and the puncture traveled 10 mm into the fried breaded shrimp. The penetration force of crust (hardness) was obtained for fifteen replicates per sample.

Sensory test of fried breaded shrimp was performed. The frozen prefried breaded shrimps were fried at 170°C for 3 min. Both treated and control samples were fried at the same time in a partitioned basket. After frying, the samples were placed on a precoded styrofoam plate and served to the panelist within 20 min. Fried breaded shrimp coated with MC (incorporated into predusting mix) and control were evaluated by the 36 untrained panelists. Panelists had been instructed to eat at least one-third of each sample and to rinse their mouth with water between samples. Cups were provided for expectoration of samples if the panelists did not wish to swallow the samples. Directional Paired Difference Test (Two Alternative Force Choice) was performed to determine if the panelists could distinguish the crispness between treated and control samples. Each sample was coded with three digit random numbers and both presented to the panelist in balanced and randomized order. The panelists were asked to taste the samples from the left to the right and indicate which of two samples was crisper. Hedonic scale was used by panelists to evaluate texture, appearance, color, aroma, flavor, and overall. These attributes were rated on a 9-point hedonic scale (Peryam and Pilgrim, 1957) wherein 9 = like extremely, 8 = like very much, 7 = like moderately, 6 = like a little, 5 = neither like nor dislike, 4 = dislike a little, 3 = dislike moderately, 2 = dislike very much, 1 = dislike extremely. Two fried breaded shrimps were presented to panelists monadically. All panel sessions were conducted in sensory panel both illuminated with a 60W daylight blue light.

Consumer acceptability test was conducted on treated breaded shrimps. The frozen prefried breaded shrimps were transported in coolers to the testing area. The treated samples were fried in soybean oil at 170°C for 3 min and drained for 1 min. After frying, two pieces of samples were placed on the styrofoam plate and served to the consumers within 20 min. One hundred and forty eight consumers participated in this study. Participants were local residents of the southern part as well as faculty staff and students at Prince of Songkla University (PSU). Consumer test was conducted on the PSU Open Week. The consumers were presented with the sample treated with MC and asked to rate their overall liking and acceptance of flavor, texture appearance, color and aroma on 9-point hedonic scale (Peryam and Pilgrim, 1957) using a paper ballot. After the consumer evaluation, they were asked to provide demographic information including gender, age, education level, income and information about their general preferences for breaded seafood.

2.3 Statistical analysis

Statistical analysis was performed using General Linear Model (GLM) to test the effects of edible coatings ingredient incorporated into predusting mix on the product's moisture and fat content. Duncan's Multiple Range Test (DMRT) was used to estimate the significant differences among the means at 95% confidence levels. The sample t-test was applied to analyze the significant differences of firmness and tenderness between the control and treated samples (SAS, 1989).

3. Results and Discussion

3.1 Effect of incorporated coating ingredients on barrier properties and physical properties of breaded potatoes

1) Moisture and fat barrier properties

This experiment investigated the effect of edible coating ingredients incorporated into predusting mix using HPMC, MC and WG. The effect of type and concentration of edible ingredients incorporated into predusting mix on moisture and fat content of fried breaded potato were determined. It was found that HPMC, MC and WG could reduce moisture loss and fat absorption in core, crust and intact portion of fried breaded potato when incorporated into predusting mix (Figure 1).

In the core portion, the moisture content of core portion increased when HPMC, MC and WG were applied compare to control, especially when the MC concentrations increased up to 6%. No significant difference in increasing moisture retention was found between 6% MC to 12%MC. The similar favorable effect was found when the HPMC concentrations increased up to 9%, while a non-significant difference in increasing moisture retention was found between 9% and 12% HPMC. WG had less effect in increasing the moisture retention in the core portion of fried breaded potato than MC and HPMC. Increasing in WG con-

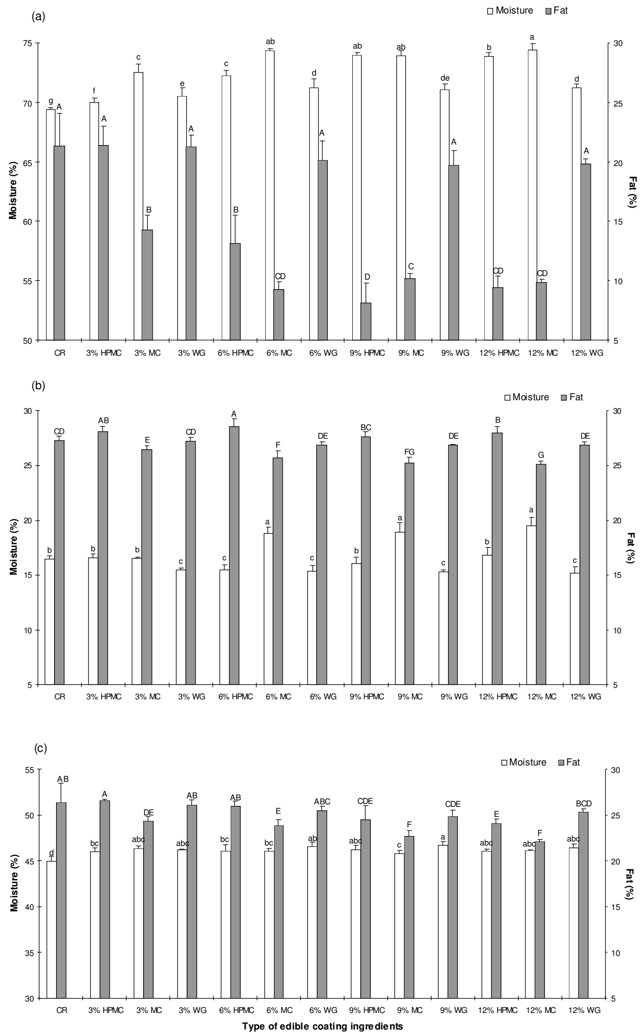

Figure 1. Effect of edible coating ingredients incorporated into predusting mix on the moisture and fat content of fried potato; core (a), crust (b) and intact (c); For each moisture and fat value, bars with different letters are significantly different (p≤0.05); CR = control, 3-12% HPMC = 3-12% of hydroxypropyl methylcellulose incorporated into predusting mix, 3-12% WG = 3-12% of wheat gluten incorporated into predusting mix

centrations up to 6% resulted in significantly increased moisture content compared to control. For the fat content, increasing HPMC concentrations from 9% to 12% resulted in significantly decreased fat absorption compared to control, whereas increasing MC concentrations from 6% to 12% resulted in significantly reduced fat absorption. However, there was no significant difference between control and WG treated samples. This indicated that WG had no effect on reducing fat absorption in the core portion. Overall, upon comparing the effects of all three edible coating ingredients on moisture and fat content of the core portions of fried samples, it was found that MC was more effective than HPMC and WG (Figure 1a).

In the crust portion, the moisture content of crust was not significantly different between control and HPMC treated samples, except that 6% HPMC showed significantly lower moisture content. Increasing the MC concentration up to 6% resulted in significant increase in the moisture retention. Increased moisture loss was found in product crust of the sample treated with WG. The fat content of the crust was significantly higher in sample treated with HPMC, except 9% HPMC did not differ significantly. The sample treated with MC showed significantly lower fat content than control, while the WG treated crust was not significantly different in the fat content (Figure 1b).

In the intact samples, the moisture content of those treated with HPMC, MC and WG were statistically higher than in the control. However, treatments using different concentrations of HPMC, MC and WG did not show any clear trend in reduction of moisture loss. The fat content of the intact sample was significantly lower than that of the controls for the samples treated with HPMC and MC. Fat content decreased to a greater extent at higher level of MC, and the same trend was observed with increasing HPMC concentration (Figure 1c).

Results showed that MC was more effective than HPMC and WG in moisture loss and fat absorption reduction. Similarly, Ang (1993) reported that the fat content of fried batter was reduced when 1% powdered cellulose with fiber size greater than 100 mm was incorporated into the batter. In addition, the moisture content increased in these coatings. The result from our study also showed trends similar to as reported by Garcia *et al.* (2002) that MC coatings were more effective in reducing fat uptake in deep fat frying potato strips and dough discs than HPMC. The variation in moisture and fat barrier properties could be related to the microstructure of the coating regarding to the composition. Llorca *et al.* (2005) observed the microstructure of frozen batter coated products prepared by an innovative process using scanning electron microscope and found that batter prepared with MC had smaller cells than those prepared without MC. After thermal impact by immersing the batter coated product in hot water, the coating developed a consolidated structure and may minimize the possibility of damage to the structure. Llorca *et al.* (2001) studied the effect of frying on the microstructure of frozen squid rings and stated that gas cells form in the batter layer generated by the CO_2 from the leavening agent during frying and also by the release of water vapor, and these gas cells help the fat to penetrate the layer of batter. In this study, the fat uptake in the sample may be affecting by the water vapor transmission during frying.

2) Texture property of breaded potatoes

The textural properties of control and treated sample with 6%MC were evaluated. It was found that the product hardness of sample treated with 6% MC (2563±144 N) was significantly lower compared to control (2690±151 N), whereas

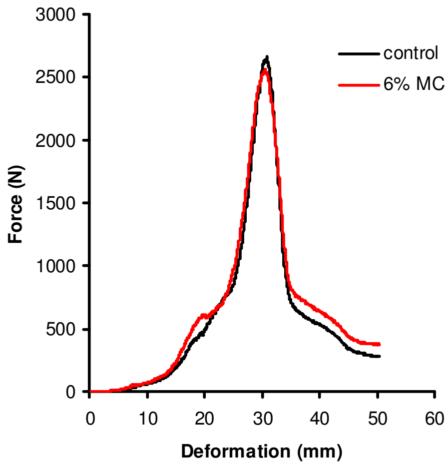

Figure 2. Texture profile of control and 6% MC coated breaded potatoes

the shear energy was not significantly different between 6% MC (15.5±1.0 J) and control (15.2±1.0 J). However, the texture profile (Figure 2) indicated that the control and treated sample had similar textural characteristics. The maximum peak force of the control was greater than the treated sample, possibly due to moisture loss. Atkins (1987) reported that the mechanical properties of biological materials normally increase with decreasing moisture.

The application of edible coating ingredient incorporated into predusting mix showed favorable properties as compared with direct film coating on the product surface (Albert and Mittal, 2002; Chinnan and Mallikarjunan, 1997; Garcia *et al.*, 2002) or incorporating the edible film ingredient into batter (Sanz *et al.*, 2004a). The advantage of this application can be easily introduced into the production process without additional process step. The application of edible coating ingredient, methylcellulose incorporated into predusting mix at 6% concentration was selected and used in a commercial breaded shrimp product.

3.2 The application of edible coating ingredient in breaded shrimps

1) Moisture and fat barrier properties

The moisture content of control sample of prefried breaded shrimps was 74.8±0.2, 36.5±0.3 and 54.4±0.6% for core portion, crust portion and intact, respectively. The moisture content of treated prefried breaded shrimps (containing 6% MC in predusting mix) was 76.5±0.1, 36.9±0.2 and 55.9 ±0.5%, respectively, for core portion, crust portion and intact. Moisture content of core and intact of prefried breaded shrimp containing 6% MC was significantly higher than control. However, there was no significant effect on moisture content of crust.

The fat content of control sample of prefried breaded shrimps was 6.6±0.4, 39.5±0.2 and 31.0 ±0.2% (dry basis) of core, crust and intact of breaded shrimp containing 6% MC after final frying. The moisture content of treated samples was significantly higher than control in all portions.

The fat content of control final fried breaded shrimps was 9.9±0.2, 37.6±0.4 and 31.7 ±0.4% (dry basis) for core, crust and intact, respectively. The fat content of treated final fried breaded shrimps (containing 6% MC in predust) was 9.7±0.1, 37.4±0.2 and 29.7 ±0.3% (dry basis) for core, crust and intact, respectively. The fat content of control core and intact was significantly higher than treated breaded shrimp; however, no significant difference in fat content of control and treated crust portion (Figure 4) was observed. The increase in moisture was observed in all portions, meanwhile the decrease in fat absorption was observed only in the core portion and intact. This result indicated that the location of edible coating ingredient affected the migration of moisture and fat. The inconsistent barrier to moisture and fat of edible film was found by Holownia *et al.* (2000) that edible film applied to chicken strips prior to breading had fried crust with higher fat and lower moisture levels. The difference in moisture and fat may be partly due to the fact that the product absorbed fat during the prefrying process. Moreover, during freezing a series of fissures could have generated in the substrate and the layer of batter (Llorca *et al.*, 2003). These fissures were probably caused by the growth of water crystals, which may favor subsequent release of moisture and penetration of fat during frying. This effect probably has less impact on the product prepared with edible coating ingredient.

2) Textural property

The maximum shear force values (hardness), shear energy (area up to peak force) and puncture force to penetrate the crust (crust hardness) of breaded shrimp with and without MC edible coating ingredient are shown in Table 1. The hardness of control breaded shrimp was significantly higher than the sample containing 6%MC. However, the shear energy was not significantly different between the two samples. Sanz *et al.* (2004b) found that the peak force values (hardness) of battered squid ring obtained immediately after frying were greater for 2% MC batters than the control. With regard to the effect of time elapsed after frying on the texture property, the sample showed a decrease in hardness and became softer with time. This phenomenon seems not to have much effect in breaded shrimp for this study, possibly because the water retention did not increase significantly. The crust hardness of breaded shrimp was significantly higher in control than treated sample. The greater force to penetrate the crust of control breaded shrimp was probably due to the moisture loss of the sample. Control breaded shrimp retained less moisture than those samples containing MC.

Table 1. Mean values[1] of peak force and energy from Kramer Shear test and mean values of force to penetrate the crust of breaded shrimps

Treatment	Kramer shear test		Puncture test
	Peak force (N)	Energy (J)	Force (N)
Control	205.59[a] (±12.21)	112.07[a] (±12.97)	1.06[a] (±0.30)
6%MC	182.51[b] (±7.07)	108.29[a] (±9.41)	0.90[b] (±0.21)

[1] Mean within a column with differing superscripts are significantly different ($p \leq 0.05$)

3) Sensory evaluation

Mean hedonic rating for appearance, color, flavor, taste, texture and overall liking of breaded shrimp with and without MC edible coating ingredient are presented in Table 2. The control sample was rated between 6.8-7.6, meanwhile the sample containing 6%MC was rated between 7.0-7.4 in all attributes. Texture and overall liking received higher scores compared to control. In all cases, attributes were rated a "like slightly" to "like moderately" which were not statistically different for control and treated breaded shrimps. These results indicated that no off flavor and texture was detected considering to the presence of the edible coating ingredient. Garcia *et al.* (2002) reported that edible coatings affected the color differences between coated and uncoated dough fried samples but did not modify the textural characteristic. In any case, all attributes were acceptable to the sensory panels.

Directional paired different test found that the treated breaded shrimp was significantly higher in product crispness compared to control. The twenty four panelists of thirty six rated the treated breaded shrimp (containing 6% MC) as having more crispness ($p \leq 0.05$). However, the instrument textural property showed that the hardness of treated sample was significantly lower than control, which contrasted with the sensory data (Table 2) and discriminative test, especially the crispness. This may due to the moisture retention prop-

Table 2. Mean hedonic rating[1] of breaded shrimp for control and sample containing edible coating

Attribute	Mean hedonic rating (±sd)	
	Control	MC incorporated
Appearance	7.3 (±0.9)	7.4 (±0.7)
Color	7.6 (±0.8)	7.4 (±0.6)
Flavor	6.9 (±1.2)	7.0 (±1.0)
Taste	7.2 (±1.3)	7.2 (±1.1)
Texture	6.8 (±1.5)	7.2 (±1.0)
Overall liking	6.9 (±1.2)	7.3 (±0.8)

[1] Ratings are based on a 9-point hedonic scale where 1 = dislike extremely, 5 = neither like nor dislike, and 9 = like extremely

Table 3. Demographic information of consumers

Variable	Category	N	Percentage
Sex			
	Male	50	33.8
	Female	98	66.2
Age (years)	<15	5	3.4
	15-25	72	48.6
	26-35	26	17.6
	36-45	21	14.2
	>45	24	16.2
Educational Level	Some high school or less	4	2.7
	Completed high school or equal	17	11.5
	Some college or equal	17	11.5
	Bachelor degree	82	55.4
	Higher than bachelor degree	26	17.6
	No answer	2	1.3
Occupation	Student	72	48.7
	Employee of private company	6	4.0
	Officer	46	31.1
	Employee of state enterprises	3	2.0
	Owner	11	7.4
	Others	10	6.8
Monthly Income (Baht)	<2,500	16	10.8
	2,501-5,000	22	14.9
	5,001-7,500	28	18.9
	7,501-10,000	15	10.1
	10,001-12,500	13	8.8
	12,501-15,000	6	4.0
	15,001-17,500	9	6.1
	17,501-20,000	7	4.7
	>20,000	18	12.2
	No answer	14	9.5

erty of MC. The control sample might have provided a drier and tougher texture, while the MC treated samples provide a moister and softer texture.

4) Consumer acceptability

One hundred and forty eight consumers participated in this study. Their demographic characteristics are shown in Table 3. The population consisted predominantly of women, approximately two thirds (66%) of the total. Forty eight percent of the participants were between 15-25 years of age. Fifty five percent consumers had completed their bachelor degree and 17.6% had their education level higher than bachelor degree. Forty eight percent of participants were students and 31% were employed full time in a government sector. The individual income of the consumer was composed of 18.9% earned 5,001-7,500 Baht/month, 14.9% earned 2,501-5,000 Baht/month and 12.2% earned more than 20,000 Baht/month.

Ninety percent of the participants liked breaded seafood. One hundred percent accepted the breaded shrimp product containing 6% MC. Eighty seven percent of participants indicated that they would be willing to buy breaded shrimp with lower fat content than the similar product available in the market. Most consumers (73%) were willing to pay the same price for this product as they were paying for the similar commercial product (Table 4).

Mean hedonic rating for sensory attributes and overall acceptability of breaded shrimp containing 6% MC are shown in Table 5. Consumer panelists' rating for overall liking of appearance (mean = 7.9) indicated that the appearance of breaded shrimp containing 6% MC was acceptable. Based on the percentage of consumer panelists who rated the overall appearance above 6 ("like slightly"), the majority (96.0%) of these consumers liked the appearance of breaded shrimp. Consumers liked the color and their rating means were 8.1 ("like very much"). The color of breaded shrimp containing 6% MC was acceptable to the majority of consumer

Table 4. Consumer's acceptance and willingness to buy and amount to pay for breaded shrimps

Question	Category	N[1]	Percentage
Do you like breaded seafood product?	Yes	134	90.5
	No	10	6.8
	No answer	4	2.7
Is this product acceptable?	Yes	14	100
	No	80	0
Would you like to buy this product if it was commercially available and had lower fat content than similarcommercial product?	Yes	130	87.8
	No	21	1.4
	Not sure	6	10.8
How much would you be willing to pay for this product compared to similar commercial product?	Lower price	35	23.6
	Same price	10	73.0
	Higher price	85	3.4

[1]N = number of responses

Table 5. Mean hedonic rating[1] for breaded shrimps containing edible coating ingredient

Attribute	Mean hedonic rating (±sd)
Appearance	7.9 (±0.8)
Color	8.1 (±0.8)
Flavor	7.7 (±1.0)
Taste	8.0 (±0.9)
Crispness	8.2 (±0.7)
Overall liking	8.0 (±0.7)

[1] Ratings are based on a 9-point hedonic scale where 1 = dislike extremely, 5 = neither like nor dislike, and 9 = like extremely

panelists (96.6%) that rated this attribute as good (score > 6). The flavor and taste were rated good. Consumer panelists indicated that they liked overall flavor "moderately" to "like very much" (mean = 7.7) and liked the overall taste "very much" (mean = 8.0) of breaded shrimp containing 6% MC. In general, the flavor and taste were acceptable to the majority of consumer panelists who rated score > 6 for 90.5% and 96.0%, respectively. Consumers rated the crispness of breaded shrimp as "like very much" (mean = 8.2). The crispness was acceptable to the most of consumer panelists (98.7%). The consumer panelists rated the breaded shrimp containing 6% MC as "like very much" (mean = 8.0) with regard to overall acceptability. About 99% of consumer panelists rated this breaded shrimp with score > 6. All of the consumers (100%) accepted the shrimp containing 6% MC.

4. Conclusions

Incorporating edible coatings into predusting mix was found to be promising in practical application. In this investigation, hydroxypropyl methylcellulose (HPMC) and methylcellulose (MC) coatings reduced moisture loss and fat absorption more effectively than wheat gluten (WG). MC at 6% was the most effective of all predusting treatments. The application of 6% methylcellulose incorporated into predusting mix in commercial breaded shrimp product retained the moisture and reduced the fat uptake of prefried and final fried breaded shrimp. The final fried breaded shrimps containing 6% methylcellulose were lower in overall product hardness and crust hardness. The treated final fried breaded shrimps had similar rating as untreated breaded shrimp for appearance, color, flavor, taste, texture, overall liking and higher in product crispness. Consumers found the sensory attributes of treated fried breaded shrimps to be very acceptable and expressed a willingness to buy this type of product. Consumers would be willing to pay the same price for this product as they were paying for similar commercial products.

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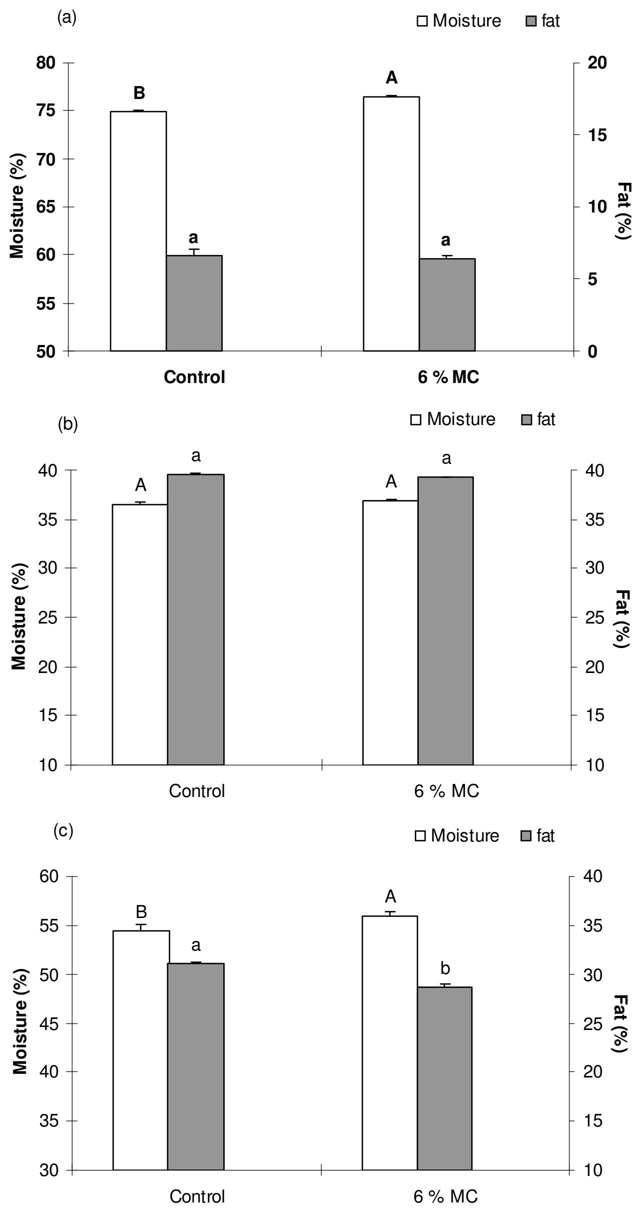

Figure 3. Moisture and fat contents of prefried breaded shrimp; core (a), crust (b), and intact (c); for each moisture and fat values, bars with different letters are significantly different ($p \leq 0.05$)

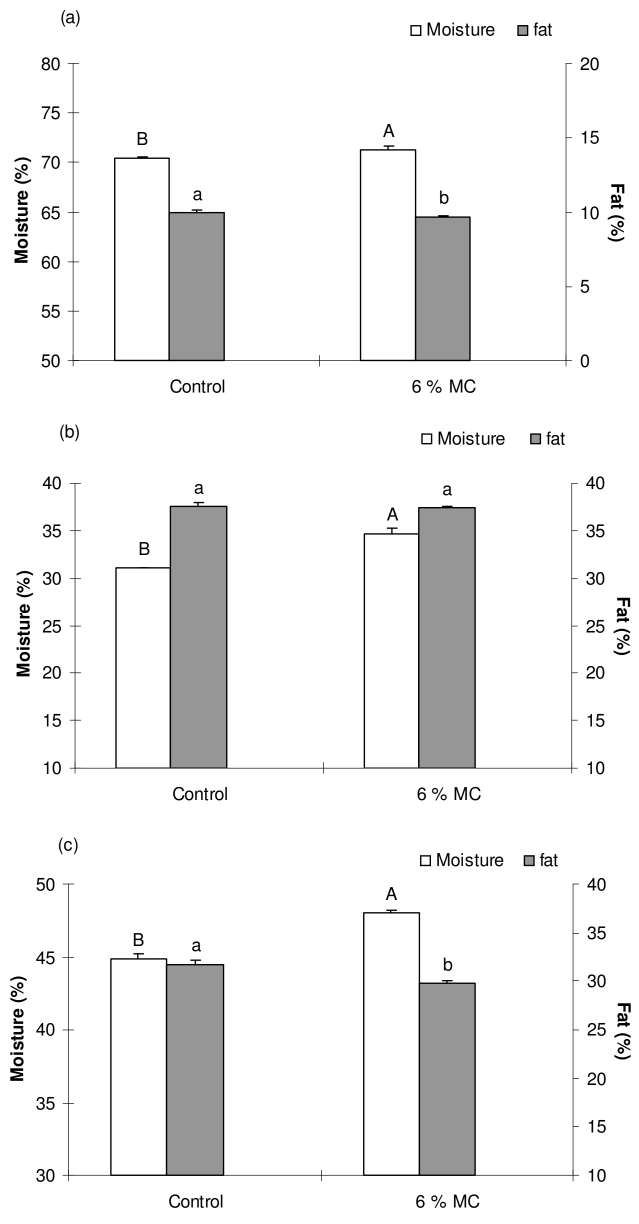

Figure 4. Moisture and fat contents of final fried breaded shrimp; core (a), crust (b), and intact (c); for each moisture and fat values, bars with different letters are significantly different ($p \leq 0.05$)

for core portion, crust portion and intact, respectively. The fat content of treated prefried breaded shrimps (containing 6% MC in predusting mix) was 6.4±0.2, 39.2±0.1 and 28.7 ±0.3% (dry basis) for core portion, crust portion and intact, respectively. The fat content of breaded shrimp intact treated with 6% MC was significant lower than control, whereas there was no difference in core and crust segments (Figure 3). The results showed the effectiveness of using MC to increase moisture retention and reduce fat absorption after the prefrying step. This result agreed with previous studies reported by Sanz *et al.* (2004a). They found that 1, 1.5 and 2% MC batters retained 43.8, 62.0 and 75.3% more moisture and reduced 39.0, 63.9 and 78.4% fat in comparison to control battered squid ring after prefrying at 190°C for 30 s. However, in this study using different mode of application and frying conditions could be attributed to the different effects.

The moisture content of control sample of final fried breaded shrimps was 70.4±0.2, 31.0±0.1 and 44.8 ±0.4% for core portion, crust portion and intact, respectively. The moisture content of treated fried breaded shrimps (containing 6% MC in predusting mix) was 71.3±0.3, 34.7±0.5 and 48.0 ±0.3% for core portion, crust portion and intact, respectively. Noticeable effects were observed in moisture content