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ORIGINAL ARTICLE

Production of low-fat shrimps by using hydrocolloid coatings

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Abstract Production of low-fat fried foods by using hydrocolloid coatings is a common method to avoid excessive oil absorption during deep-fat frying. The aim of this work was to evaluate the influence of hydrocolloid coatings (carboxymethyl cellulose, guar, tragacanth and zedo gum) on the oil content and quality parameters of shrimp after deep-fat frying. The hydrocolloid solutions (0.5, 1.0 and 1.5 %*w/v*) were used for coating. Coated and uncoated (control) samples were packaged and stored at −20 and after a week were fried at 170 °C for 90 s in sunflower oil. The results showed that all hydrocolloid coatings reduced oil content of fried shrimp. The coated shrimps with 1.5 % tragacanth solution had highest coating pick up and moisture content, and lowest oil content than the other samples. The coated samples had darker color and softer texture than the control sample. Sensory evaluation indicated that all coated and uncoated shrimps were acceptable.

Keywords Hydrocolloid coating · Deep-fat frying · Oil absorption · Shrimp

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Introduction

Fried foods are very delicious. However, contain high amount of fat sometimes 1/3 of the total food weight (Mellema 2003). The fried foods consumption plays important role in the development of obesity and coronary heart disease. Hence, food researchers and manufacturers attempt to produce low-fat fried foods in recent years. Several pretreatment methods have been performed for reduction of oil content in fried foods such as coating, osmotic dehydration, air drying, blanching (Albert and Mittal 2002; Krokida et al. 2001; Pedreschi and Moyano 2005; Sanz et al. 2004). Coating based on hydrocolloids is a common method to prevent excessive oil absorption during deep-fat frying. Hydrocolloids due to film-forming ability could provide good barrier against oil penetration into fried foods (Albert and Mittal 2002). In order to access this purpose, gums are used in very low concentrations (0.5–2 %) in batter formulation or edible film (Varela and Fiszman 2011). The wide variety of gums have been tested as oil barriers in fried foods such as cellulose derivatives, guar, xanthan, gellan, pectin, alginate, soy protein isolate, locust bean gum, gelatin, carrageenan (Sothornvit 2011; Singthong and Thongkaew 2009; Albert and Mittal 2002). There are enormous resources of natural gums in Iran, such as tragacanth and zedo. However, few studies have been performed on their oil barrier property to decrease oil absorption. Tragacanth and zedo are dried exudation obtained from the Asiatic species of *Astragalus* and *Amigdalus*, respectively (Balaghi et al. 2011; Fadavi et al. 2014). The effects of different hydrocolloids have been studied on oil content and quality parameters of many products such as french-fries (Pahade and Sakhale 2012; Khalil 1999), banana and potato chips (Singthong and Thongkaew 2009; DaraeiGarmakhany et al. 2008), battered foods containing fish and chicken nugget (Chen et al. 2008; Sahin et al. 2005), battered squid ring, pork patty, marrow, cheese and carrot slices (Salvador et al. 2008;

Akdeniz et al. 2006), and Indian traditional snacks such as sev, samosa, papad and boondis (Annapure et al. 1999; Sakhale et al. 2011; Patil et al. 2001; Priya et al. 1996). Shrimp is popular seafood in the world due to its unique flavor and texture (DehghanNasiri et al. 2012). Frying in oil is one of the common cooking methods of shrimp. However, no information about the effects of hydrocolloid coatings on oil content of fried shrimp is available. The aim of this present study was to investigate the influence of different hydrocolloid coatings (carboxyl methylcellulose, guar, tragacanth and zedo gum) on oil and moisture content, coating pick up, color, texture and sensory parameters of shrimp after the deep-fat frying.

Materials and methods

Preparation of Shrimps

The frozen shrimps (*Litopenaeus vannamei*) with an average weight of 15–20 g were purchased at a local market and transported to the seafood processing laboratory. The frozen shrimps were thawed at room temperature and then decapitated, peeled and deveined by hand. Before the coating, the surface moisture of shrimps was removed to improve the adhesion of coating solution.

Preparation of coating solutions

Tragacanth and zedo were purchased from local grocery shops in Kermanshah province, Iran. Carboxymethyl cellulose (CMC) and guar were obtained from Titran Chemical Company, Iran. The hydrocolloid powders at different concentrations (0.5, 1.0 and 1.5 %) were mixed with distilled water (60 °C) using a homogenizer (IKA T25-Digital Ultra Turrax, Staufen, Germany) at speed 7,000 rpm for 30 s and finally used as coating solutions.

Coating, draining and frying process

The shrimps were individually immersed in the hydrocolloid solutions for 30 s. The shrimps without hydrocolloid coatings were used as the control. All samples (coated and uncoated) were drained on reticular tray and placed into a convection oven at 150 °C for 10 min to decrease the surface moisture (Khalil 1999). The samples after cooling at room temperature were packaged in LDPE bags and stored at −20 °C for a week (Salvador et al. 2002). Finally, all samples were fried without thawing at 170 °C for 90 s in domestic deep fryer (Moulinex Toucan Automatic fryer, Portugal) containing 2 l sunflower oil. A thermocouple was connected to the fryer to monitor the temperature and level of oil was checked, continuously.

Experiments

Coating pick up calculation

The coating pick up was obtained by considering the weight of raw coated shrimp and initial weight of raw uncoated shrimp and calculated according to the formula (Chen et al. 2008).

$$\%\,Coating\,pick\,up\frac{A-B}{A}\times 100$$

A Weight of raw coated shrimp after drip for 1 min (g)
B Initial weight of raw non-coated shrimp (g)

Oil and moisture content

The moisture content of fried shrimp was determined by considering the weight difference sample before and after drying in an oven at 105 °C for 24 h. The oil content of dried sample (dry basis) was measured by soxhlet extraction with petroleum ether for 6 h (AOAC 2005).

Color measurement

Around 15 min after frying process, the color of three fried shrimps from each treatment were measured using a colorimeter (Lovibond CAM-system, England 500). The results were presented in accordance the CIE L* (lightness), a* (redness/greenness), and b* (yellowness/blueness) values.

Texture measurement

Around 30 min after frying process, texture analysis of the fried shrimps were performed using a LFRA texture analyzer (LFRA 4500, Brookfield, USA) based on penetration test by a cylindrical stainless steel probe (2 mm Diameter). The texture analyzer was set to a speed of 60 mm/min for 40 % penetration.

Sensory evaluation

The sensory evaluation was performed by 15-member semi-trained panelists. The panelists evaluated the color, appearance, flavor, odor, texture and overall acceptability of fried shrimps based on a nine point hedonic scale (1: dislike extremely to 9: like extremely).

Statistical analysis

All experimental observations and analytical measurements were done in triplicate and mean values±standard deviations were reported. Experimental data were analyzed by analysis of variance (ANOVA) and Duncan's multiple range test at 5 %

level of significance was applied for comparison of treatment means. Non-parametric Kruskal-Wallis test and Mann Whitney U test were used for analysis of sensorial data. The statistical analysis was performed using the SPSS version 16.0 software program (SPSS Inc., Chicago, IL, USA).

Results and discussion

Coating pick up

The effect of hydrocolloids at different concentration on coating pick up of shrimps showed in Table 1. Coating pickup is the amount of hydrocolloid solution that adheres to a raw shrimp (Varela and Fiszman 2011) and changes the quality parameters of fried foods (Akdeniz et al. 2005). Viscosity of hydrocolloid solutions plays an important role in the quantity of coating pickup (DehghanNasiri et al. 2012; Dogan et al. 2005; Chen et al. 2008; Altunakar et al. 2006). The highest coating pick up was obtained when samples coated with tragacanth solution at 1.5 % while, those coated using zedo solution at 0.5 % had the lowest coating pick-up. The high amount of coating pick up in 1.5 % tragacanth gum may be due to its high apparent viscosity or high adherence. There were no significant differences between CMC and Guar gum with similar concentrations in coating pick-up ($p>0.05$). In general, by increasing the hydrocolloid concentration, more hydrocolloid solution remained on the sample, thus coating pick up percentage was increased. The similar findings are also reported by DaraeiGarmakhany et al. (2012) and Amboon et al. (2012).

Oil content

The results showed that all hydrocolloid coatings except zedo gum at concentrations (0.5, 1.0 %) had significant effect on reduction of oil content in fried shrimp (Table 2). The poor oil-barrier ability of zedo gum may be due to its low coating pick up or lack of thermo-gelling property (Fadavi et al. 2014). Because thermo-gelling is important functional property that effective on reduction oil content in fried foods (Sahin et al. 2005). Coating pick up also influences the amount of oil absorption of coated products during deep-fat frying (Amboon et al. 2012; Altunakar et al. 2006; Akdeniz et al. 2005; Sahin et al. 2005). The lowest oil content was observed in coated shrimps with 1.5 % tragacanth. DaraeiGarmakhany et al. (2008) reported that potato chips coated with 2 % tragacanth had highest oil content in comparison with other samples. Cellulose derivatives such as CMC are common hydrocolloids which have been studied by many researchers to reduction of oil absorption in fried foods. The reduction in oil content with 1 % CMC in samosa and French fries were 38.9 % and 56.7 %, respectively (Sakhale et al. 2011; DaraeiGarmakhany et al. 2012) while on shrimp in present work was 27.6 %. These different results could be the reason of difference between food matrix. Composition of product (e.g. moisture, solids, fat, protein) (Pinthus et al. 1993) and microstructure of product (Dana and Saguy 2006) are efficient factors on the quantity of oil absorption during frying process. Also, the intense deformation of shrimp during deep-fat frying may be damage to hydrocolloid coatings and reduce their oil-barrier performance. Therefore, it seems that the type of foodstuff is important factor on amount of oil reduction by

Table 1 Effect of different hydrocolloid coatings on coating pick-up of shrimps

Treatment	Hydrocolloid concentration (%)	Coating pick up (%)
Control	–	–
	0.5	5.96±0.36[fg]
CMC	1.0	8.88±1.10[ef]
	1.5	17.29±2.99[b]
	0.5	8.55±0.82[fg]
Guar gum	1.0	12.42±2.17[de]
	1.5	16.5±2.12[bc]
	0.5	13.21±1.50[cd]
Tragacanth gum	1.0	17.92±2.80[b]
	1.5	26.94±4.31[a]
	0.5	4.84±0.77[g]
Zedo gum	1.0	5.71±0.93[fg]
	1.5	8.82±1.12[ef]

Means with different small letters in the same column represent significant difference at 5 % level of significance ($p<0.05$)

Table 2 Effect of different hydrocolloid coatings on oil and moisture content of deep-fat fried shrimps

Treatment	Hydrocolloid concentration (%)	Oil content	Moisture content
Control	–	13.4±0.47[a]	51.25±0.54[j]
	0.5	11.58±0.31[c]	58.7±0.32[g]
CMC	1.0	9.7±0.22[d]	62.43±0.2[de]
	1.5	8.8±0.53[e]	64.26±0.75[c]
	0.5	11.6±0.6[c]	60.15±0.82[f]
Guar gum	1.0	10.2±0.47[d]	62.65±0.45[d]
	1.5	9.65±0.3[d]	65.92±1.42[b]
	0.5	12.56±0.52[b]	61.25±0.23[ef]
Tragacanth gum	1.0	10.18±0.25[d]	64.8±0.66[bc]
	1.5	8.1±0.28[f]	67.74±1.34[a]
	0.5	13.05±0.34[ab]	52.85±0.41[i]
Zedo gum	1.0	12.92±0.28[ab]	53.62±0.93[i]
	1.5	12.45±0.36[b]	55.07±0.72[h]

Means with different small letters in the same column represent significant difference at 5 % level of significance ($p<0.05$)

the hydrocolloid coatings (Kim et al. 2011). Although both 1 % CMC and 1.5 % zedo gum showed same pick up value, however coating with 1 % CMC showed more reduction in oil absorption that may be due to its film formation property or thermo-gelling ability (Annapure et al. 1999; Varela and Fiszman 2011).

Moisture content

The moisture content of shrimps after frying process showed in Table 2. The results showed that moisture content of all coated samples were higher than the control (uncoated shrimps). This result is in accordance with result of previous studies (Singthong and Thongkaew 2009; Garcia et al. 2002; Khalil 1999; DaraeiGarmakhany et al. 2008; Albert and Mittal 2002). As the gum concentration increased, the moisture content increased, while the oil content decreased. Holikar et al. 2005; Patil et al. 2001; Sakhale et al. 2011 have also reported the similar trend in various types of fried food products treated with hydrocolloids. The results indicate that 1.5 % tragacanth had most effective on reduction moisture loss of shrimps during deep-fat frying. The better performance of tragacanth at 1.5 % concentration to reduction moisture loss and oil uptake may be due to high coating pick up which provided a thick layer with best barrier properties. Even, the effect of thermo-gelling property of CMC at concentration 1.5 % on reduction moisture loss and oil uptake was lower than1.5 % tragacanth.

The structural changes in product during frying process causes moisture loss (Dana and Saguy 2006). The moisture loss will lead to increase in porosity of product (Mellema 2003; Dana and Saguy 2006). During deep-fat frying, oil fills the pores and replaces the moisture (Pinthus et al. 1993; Mellema 2003; Dana and Saguy 2006). In present research, the control samples had highest oil content due to high moisture loss. However, coatings as barrier could prevent the moisture loss and oil uptake (Mellema 2003; Singthong and Thongkaew 2009). Therefore, all coated shrimps had lower moisture loss and oil uptake compare to control.

Color measurement

Results obtained from color measurement indicated that all coated shrimps had darker color than control (Table 3), that may be due to the increase in the rate of Maillard browning reaction, because the hydrocolloid coatings have nature of carbohydrates. The lightness of samples was decreased by increasing of guar concentration, so that the darkest color was observed in the coated shrimps with 1.5 % guar gum solution. The shrimps coated with 1.5 % zedo gum solution had higher red color than the other samples. This may be depending on reddish color of the zedo gum solution. The hydrocolloid coatings at different concentrations did not show any significant effect on yellowness of shrimps (p>0.05).

Texture measurement

Hydrocolloid coatings have a significant impact on the textural properties of French fries and banana chips (Khalil 1999; Singthong and Thongkaew 2009; DaraeiGarmakhany et al. 2012), while Rayner et al. (2000) and Garcia et al. (2002) reported that coating with soy protein films and cellulose derivatives (MC and HPMC) no significant effect on texture of fried products (potato strip and dough disc). The results of the texture measurement of shrimps with and without hydrocolloid coatings were presented in terms of hardness (N) (Table 4). These results indicated that hardness of samples was decreased by hydrocolloid coatings. The lowest hardness was observed in

Table 3 Effect of different hydrocolloid coatings on color parameters of deep-fat fried shrimps

Treatment	Hydrocolloid concentration (%)	Color parameters		
		L	a*	b*
Control	0.5	69.02±1.16^{a}	13.34±0.54^{abc}	10.13±0.85^{a}
		66.88±0.9^{ab}	13.82±0.88^{abc}	9.68±0.6^{a}
CMC	1.0	63.73±1.35^{de}	14.45±1.01^{ab}	10.0±0.44^{a}
	1.5	62.05±1.28^{e}	13.48±1.26^{abc}	10.25±0.67^{a}
	0.5	64.14±1.02^{cde}	12.33±0.94^{c}	9.55±0.9^{a}
Guar gum	1.0	62.5±0.68^{e}	14.5±1.68^{ab}	10.71±1.02^{a}
	1.5	58.73±1.47^{f}	13.0±1.35^{bc}	10.08±0.49^{a}
	0.5	63.97±1.86^{de}	13.62±0.65^{abc}	10.75±0.84^{a}
Tragacanth gum	1.0	61.55±1.29^{e}	12.47±0.9^{bc}	9.67±0.64^{a}
	1.5	66.5±1.04^{bc}	12.82±0.77^{bc}	11.04±1.1^{a}
	0.5	65.72±2.21^{bcd}	14.35±1.32^{abc}	10.58±0.92^{a}
Zedo gum	1.0	62.6±0.95^{e}	14.42±1.11^{abc}	9.8±0.76^{a}
	1.5	63.48±1.52^{de}	15.35±1.0^{a}	10.55±0.53^{a}

Means with different small letters in the same column represent significant difference at 5 % level of significance (p<0.05)

Table 4 Effect of different hydrocolloid coatings on texture of deep-fat fried shrimps

Treatment	Hydrocolloid concentration (%)	Hardness (N)
Control	0.5	5.83±0.38^{a}
		5.0±0.34^{cde}
CMC	1.0	4.66±0.25^{defg}
	1.5	4.12±0.4^{ghi}
	0.5	4.95±0.27^{cdef}
Guar gum	1.0	4.54±0.32^{efgh}
	1.5	3.98±0.34^{hi}
	0.5	5.05±0.26^{cde}
Tragacanth gum	1.0	4.38±0.22^{fgh}
	1.5	3.78±0.45^{i}
	0.5	5.68±0.31^{ab}
Zedo gum	1.0	5.48±0.35^{abc}
	1.5	5.19±0.23^{bcd}

Means with different small letters in the same column represent significant difference at 5 % level of significance ($p<0.05$)

the shrimps coated with tragacanth solution at concentration 1.5 %. This may be due to their high moisture content and juicy texture. There is a relationship between hardness and moisture content of fried shrimps (Tables 2 and 4).

Sensory evaluation

Shrimp is delicious seafood all over the world. Therefore, the hydrocolloid coatings should not introduce undesirable effects on its sensory parameters (Varela and Fiszman 2011). The results of sensory assessment of fried shrimps with and without hydrocolloid coatings were showed in Table 5. Shrimps coated with all hydrocolloid solutions resulted in non-significant differences in all sensory parameters compared to the control ($p>0.05$). The results indicated that all shrimps (coated and uncoated) were acceptable, all scores were higher than 5. These high scores may be due to attractive and delicious taste of shrimp. It seems that sensory evaluation results are associated with color and texture analysis results. The shrimps coated with 1.5 % zedo gum had highest color score. The shrimps coated with 1.5 % tragacanth had best texture and flavor due to high juicy texture, however their appearance score due to surface slimy was lower than the other samples. The reason of surface slimy and juicy texture could be related to higher amount of coating pick up. In generally, the highest score for overall acceptability was related to coated samples with 1 % CMC.

Conclusion

In this research, the effects of hydrocolloid coatings (carboxymethyl cellulose, guar, tragacanth and zedo gum) on oil uptake and quality of fried shrimp were investigated. The hydrocolloid coatings reduced lightness and hardness of the shrimps after frying process. All hydrocolloid coatings except zedo gum at 0.5 and 1.0 % were effective to reduction the oil content of the fried shrimps. Tragacanth at 1.5 % showed most effective on reduction oil uptake. In addition, all samples (coated and uncoated) had high acceptability. This means that using hydrocolloid coatings with new method used

Table 5 Effect of different hydrocolloids on sensorial parameters of deep-fat fried shrimps

Treatment	Hydrocolloid Concentration%	Sensorial parameters					
		Appearance	Color	Flavor	Odor	Texture	Overall Acceptability
Control	–	5.64±1.43^{a}	6.17±1.62^{a}	5.56±1.22^{a}	7.18±1.18^{a}	6.65±1.1^{a}	6.18±1.29^{a}
	0.5	6.0±1.12^{a}	5.8±1.15^{a}	5.1±1.45^{a}	6.35±1.62^{a}	6.54±1.9^{a}	5.62±1.06^{a}
CMC	1.0	7.15±1.26^{a}	6.25±1.93^{a}	6.7±1.67^{a}	7.3±1.45^{a}	5.24±0.85^{a}	7.2±1.5^{a}
	1.5	6.46±2.02^{a}	5.94±1.67^{a}	7.02±1.17^{a}	6.7±1.02^{a}	6.23±2.15^{a}	5.56±1.33^{a}
	0.5	7.02±1.5^{a}	6.39±0.99^{a}	6.59±1.82^{a}	7.1±1.12^{a}	6.0±1.17^{a}	6.33±2.0^{a}
Guar gum	1.0	6.22±1.82^{a}	6.72±1.74^{a}	5.35±2.24^{a}	6.92±1.93^{a}	5.5±1.09^{a}	6.71±1.79^{a}
	1.5	5.52±1.0^{a}	5.15±1.22^{a}	7.05±1.6^{a}	7.13±0.94^{a}	6.12±2.09^{a}	5.8±1.67^{a}
	0.5	6.84±2.02^{a}	6.65±1.62^{a}	5.3±1.0^{a}	6.11±2.1^{a}	6.4±1.24^{a}	6.19±1.55^{a}
Tragacanth gum	1.0	5.93±0.98^{a}	5.22±0.85^{a}	6.37±2.08^{a}	6.58±0.88^{a}	5.75±1.01^{a}	6.75±2.1^{a}
	1.5	5.2±1.68^{a}	5.65±2.15^{a}	7.43±1.43^{a}	6.3±1.09^{a}	6.95±1.28^{a}	6.45±1.4^{a}
	0.5	6.07±1.8^{a}	5.43±1.36^{a}	6.52±0.9^{a}	7.09±1.21^{a}	5.85±2.0^{a}	5.88±1.84^{a}
Zedo gum	1.0	6.65±1.23^{a}	6.0±0.94^{a}	5.41±2.18^{a}	6.53±1.75^{a}	5.17±0.8^{a}	5.32±1.0^{a}
	1.5	5.47±1.5^{a}	6.85±1.02^{a}	7.04±1.06^{a}	6.15±1.42^{a}	6.62±1.2^{a}	6.86±1.45^{a}

Means with different small letters in the same column represent significant difference at 5 % level of significance ($p<0.05$)

in this research can be a suitable approach to industrial production of low-fat shrimp.

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