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Effect of some hydrocolloids on reducing oil uptake and quality factors of fermented donuts

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Key words: Donut, deep fat frying, carboxymethyl cellulose, pectin and guar gum.

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Abstract

By increasing obesity and the association of obesity and other health concerns with fried food consumption, the fried food industry is trying to find technologies to limit the fat uptake in fried foods. The effects of various gum types [carboxymethyl cellulose, guar gum, pectin] and their concentrations (0.35%, 0.7%, and 1%) on some quality factors of deep-fat fried donut were studied. Physical properties (moisture, oil, volume) and sensory properties of donut analyzed. As control, sample without gum addition was used. The effect of various concentrations of gums coating on the moisture content was significant. also, statistical analysis showed that coated donuts had significantly lower fat content than the control. In terms of differences weight persentage, differences volume persentage between the control treatments with other treatments, there are significant differences. Significant differences between coated and uncoated parameters L, a, b is established. Sensory evaluation showed that treated and untreated samples had similar rating for flavor, taste, texture and overall quality. The application of edible coating can be easily introduced into the production process and is beneficial to both food industry and consumers.

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Introduction

Deep-fat frying is a fast, convenient, energy-efficient cooking method in which water-containing foodstuff is immersed into frying oils at temperatures between 140 and 180C (Zolfaghari *et al*., 2013). The soft and moist interior along with the porous crispy crust provides increased palatability to foods (Akdeniz *et al*., 2006; Mallikarjunan *et al*., 1997; Mellema, 2003; Singthong and Thongkaew, 2009).

Moreover, interest in low fat products has recently increased. Fried foods also contain high amount of fat (1/3 of the total weight of the foods), yet remain popular. Interest in low fat product has recently increased as excess fat consumption is considered to heighten blood cholesterol, high blood pressure and coronary heart disease (Pinthus *et al*., 1995). Thus, improving the frying process by controlling and lowering the final fat content of the fried products has been aimed by many studies (Ziaiifar*et al*., 2008). Some practical methods are based on: the modification of frying techniques, the frying medium and surface properties (Pinthus *et al*., 1995; Mellema, 2003). Proper shaking and draining, exertion of optimum temperature and frying time (Mellema, 2003), modification of viscosity and degradation of frying oil, and application of batters or coatings (Mellema. 2003) are some alternatives. Use of hydrocolloids as coating is a method for reducing oil uptake in fried products because of their preventive properties. Hydrocolloids are widely used as functional ingredients in the food industry to add commercial value to foodstuffs. In addition to the obvious benefits of taste, texture, mouthfeel, moisture control, and water mobility, they also improve the overall product quality and stability by withstanding the demands of processing, distribution, and final preparation for the table. From a health perspective, hydrocolloids have been used in batter and breading systems to block fat absorption during deep-fat frying so that lower fat and more nutritional-coated food products could be created. (Xue and Ngadi, 2009)

Guar gum is non-gelling and is chiefly used as viscosity builder, stabilizer and water binder. They have the ability to bind water which is an important property to obtain products containing less oil since there is a strong relation between oil uptake and moisture loss during frying. (Akdeniz *et al*., 2006)

CMC forms a three-dimensional network with an ability to link water molecules within the system. They form and provide a barrier coating during heating leading to reduction in water loss and oil uptake (Xueand Ngadi, 2009; Khalil, 1999; Mellema, 2003).

The use of hydrocolloids in the food industry has become very common in the last few decades. Various ingredients such as pectin, sodium alginate (Khalil, 1999), powdered cellulose (Mallikarjunan*et al.,* 1997) were attempted. In addition, the oil-reduction effect of various gums, including hydroxypropyl methylcellulose (HPMC), guar gum, xanthan gum and gum Arabic, to batter formulation of chicken nuggets has been investigated and the results showed that HPMC and xanthan gum significantly reduced oil uptake compared with others (Sahin*et al*., 2005).

Cake donuts are characterized by a golden-brown exterior color, a crisp crust, and an inner core that resembles a baked product more than a fried food. However, donuts are fried foods and they absorb substantial amounts of oil during frying. Traditional donuts from wheat flour normally contain24 to 26% oil. (Tan and Mittal, 2006,Prosise, 1990).

The aim of this study was to evaluate the effect of guar, carboxymethyl cellulose, pectin coating and different concentration (0.35%, 0.7% and 1%) on the physical properties and sensory aspects of donut during deep-fat frying.

Materials and methods

Dough Preparation

Fermented donuts were made according to sponge-and dough method. Sponges were prepared by mixing

12 g yeast, 80 g sugar, 50 g wheat flour and 100 mL water. The sponge and the other ingredients including wheat flour (450 g), egg (100 g), butter (80 g), powder milk (20 g), lemon juice (10 mL), vanilla (1 g), salt (4 g) were mixed for 15 min. Wheat flour with other ingredients such as milk powder, salt, vanilla and baking powder were sieved. Then it was mixed with butter for 5 minutes. Other additives were added to the dough mixing continued for 10 minutes. First proofing was done at 35C for 45 min, and then proofed dough manually was rolled out to 1-cm thickness. Finally, rolled dough was cut with a manual donut cutter (inner diameter: 3 cm; outer diameter: 8.10), and again were proofed at 35C for 15 min. Schematic of dough preparation is depicted in Fig. 1. Table 1 shows chemical properties of used wheat flours analyzed according to the Iranian Standards (ISIRI 2002)

Table 1. Chemical compositions of wheat flour.

Extraction rate	Moisture %	Lipid%	Ash in dry matter %	Protein in dry matter %	Wet gluten%	pH
72%	13	7.76	0.316	9	30.67	5.8

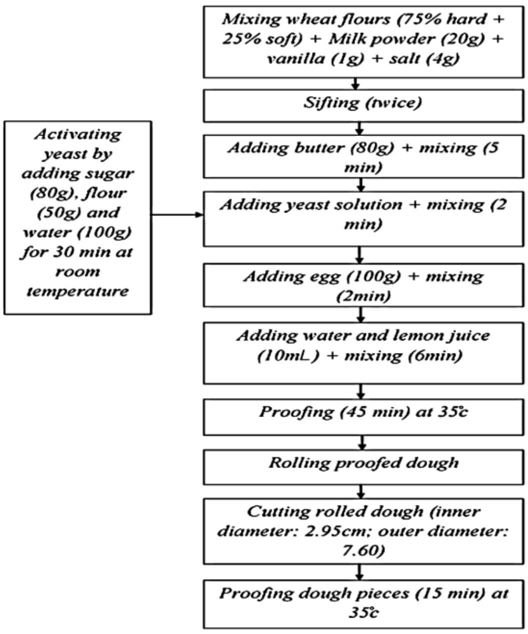


Fig. 1. Schematic of dough preparation.

Dough pieces were covered with gum solution by Immersion and immediately were fried in a domestic deep-fat fryer (1.5 L). Fryer was filled with1.5 L commercial vegetable oil (Oila, Shiraz, Iran). The fryer was rested for 10 min for temperature recovery. The oil was preheated to 150C for 1 h prior to frying to ensure that the oil temperature was stable and constant. Used oil was replaced with fresh oil after four frying batches. Samples were cooled on a paper towel for 30 min to remove surface oil.

Moisture content

Donuts were cut into small pieces (10–18 g). Moisture content was determined by measuring weight loss of fried products, upon drying in an oven at 105 until constant weight. (AACC44-15A)

Oil content

The oil content of the fried sample, was determined by extracting the previously dried sample for moisture analysis with Petroleum ether using soxhlet extraction for 6 h. Moisture and oil contents of sample were expressed as percentage of original sample in (w/w) (AACC 30-25).

Mass change and bulk volume change

Donuts were weighed before and 30 min after frying to the nearest 0.01 g. Percent mass change was calculated using Eq. (1). The bulk volume of the donuts was measured using the rapeseed displacement method (AACC International, 2000). Bulk volume measurements were preformed on both un-proofed dough and finished donuts to determine the percent change in volume (Eq. 2) (AACC 10-05)

Eq1:
$$\%\Delta m = \left(\frac{m_f - m_i}{m_i}\right)100\%$$

Eq2:
$$\%\Delta V = \left(\frac{V_f - V_i}{V_i}\right)100\%$$

Colorimetric measurements

Assays were carried out with a colorimeter CR 400 Series (Japan). The Hunter scale was used, lightness (*L*) and chromaticity parameters a^* (red–green) and b^* (yellow–blue) were measured. Samples were analyzed in duplicate, recording four measurements for each sample

Sensory Evaluations

The donut quality and sensory attributes were evaluated after cooling for 2 h at room temperature. Sensory evaluation was accomplished by the 5-point hedonic scale determination by 7 trained panelists. The panelists evaluated: shape of product, crust color and hardness, crust/crumb odor and taste.

Data Analysis

Analysis of variance and mean comparison (Duncan's new multiple range test at the 0.05 significance level), were carried out using SPSS software version 13.0 (SPSS, 2004).

Results and discussion

Moisture content

Generally, comparing the rate of moisture loss in coated and uncoated samples shows that moisture loss has higher rate in the uncoated samples than coated samples, while coated samples have the same rate. It might be referred to barrier properties of coatings. Similar results were reported for tortilla chips containing carboxymethyl cellulose (Singthong and Thongkaew, 2009). The highest moisture retention was reported when guar gum was used. This may be due to high water binding capacities of this gum (Akdeniz *et al.*, 2006). No additional retention was observed by increasing the amount of hydrocolloid added Possibly by increasing the concentration of gum retain moisture more, But water has become a constant of water Not measurable and therefore lower values are obtained. (Guarda*et al.*, 2004).Statistic analyses showed significant difference in the moisture content of coated and uncoated samples (fig 2 and table 2). Also interaction effect of coating and concentration was significant (P < 0.05) on moisture content.

Table 2. Analysis of variance of total moisture and oil content of donut.

Source of variation	d.f	Mean Square			
		Total moisture %	Oil content %	Mass change (%)	Volume change (%)
Control versus The rest	1	134.036**	783.087**	73.129**	502.417**
gum	2	1.239	7.226	0.306	3.138
concentration	2	17.904*	26.216	0.071	61.242**
Gum×concentration	4	18.268 *	93.729 *	0.276	235.959 **
Error	20	4.374	31.154	0.148	9.404
CV (%)		8.767	26.153	19.383	10.277

*, **: Significant at 1% and 5% probability level, respectively.

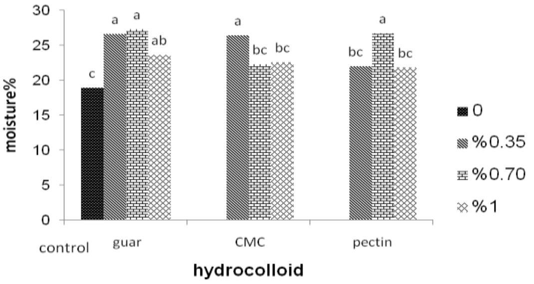


Fig. 2. Effect of type and concentration of Gum on the fat content.

Means followed by the same letter are not significantly different at P=0.05.

Oil content

The oil uptake does not happen to 100% after deep-frying. Approx. 20% of the total oil uptake takes place during deep frying and approx. 80% of the oil uptake happens after removing the fried products from the fryer (Primo-Martín *et al*, 2010). The conditions under which the donuts are removed from the frying oil seem decisive for the uptake of oil; this would be related to adhesion of oil to the surface and draining phenomena. Two main mechanisms are proposed to explain oil uptake: condensation and capillary mechanisms; in both, oil penetrates through the pores inside the product. Thus, the way by which the coating barrier limits oil uptake after frying may be attributed to the reduction of pore size and quantity (Mellema, 2003). Hydrocolloids alter the water holding capacity and consequently affect oil absorption. The results in (fig 3 and table 2) showed that, the ability of CMC and pectin to reduce oil absorption could be due to an increase in water holding capacity by entrapping the food moisture inside and preventing moisture replacement with oil (Singthong *et al*, 2009). The reduction of oil uptake in the case of guar gum may be related to their viscosity-building effect (sahin *et al*, 2005). The substantial reduction in oil uptake was mainly attributed to the barrier properties of the coatings to the transfer of moisture and fat (Mallikarjunan *et al*, 1997). ANOVA shows that control versus the rest effect were significant ($P < 0.01$). Uncoated donut had the highest lipid content.Khalil (1999) reported 40% reduction in oil uptake when he coated French fries with 0.5% calcium chloride and 5 % pectin.

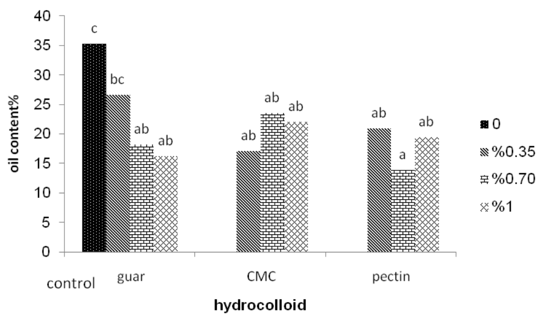


Fig. 3. Effect of type and concentration of Gum on the fat content.

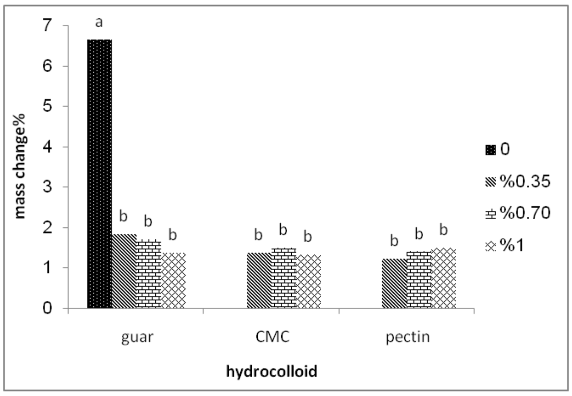
Means followed by the same letter are not significantly different at P=0.05.

Tan and Mittal (2006) stated the amount of oil uptake was directly proportional to the amount of moisture lost. In addition, frying condition and type of fried product have important effects on oil uptake during frying. Table 1 shows the effect of coating and concentration on oil uptake of donuts during frying.

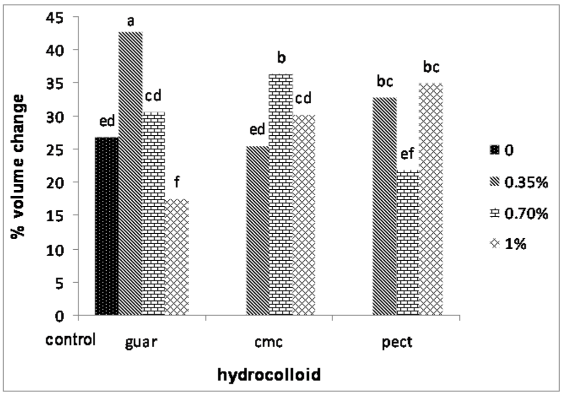
Mass change and bulk volume change

Because mass change depends upon oil uptake and moisture loss, a reduction in both moisture loss and oil uptake would result in lower mass change. Coated samples reduced mass loss significantly. No significant differences were found among the edible coatings in reducing mass loss (fig 4 (A) and Table2). The reason for lower mass loss could be attributed to the moisture retention properties of the edible films. In addition, the edible coatings acted as protective layers reducing material loss from the surface to the frying medium. (Mallikarjunan *et al*, 1997) Formation of a uniform coating on the surface of the sample is essential to limit mass transfer during frying (DaraeiGarmakhany *et al*, 2008).

The increased heat flux caused a more rapid increase in internal temperature, causing the air cells in the crumb to expand more rapidly. A higher internal temperature would also result in more rapid starch gelatinization, allowing the structure to set before the leavening gas could escape and collapse the air cell (Melito *et al*, 2013). Decrease in volume may be due to the formation of the crust and exit water vapor and Mild shrinkage Product is created. As oil was replaced with moisture and settling in porous structure, donut weights increased slightly (zolfaghari *et al*, 2013). According to the Duncan's multiple range tests, Coatings have significant effect ($p<0.01$) on volume of donuts. (Table2, fig 4(B))



(A)



(B)

Fig. 4. Effect of type and concentration of Gum on mass (A) and volume (B) of donut.

Means followed by the same letter are not significantly different at P=0.05.

Colorimetric measurements

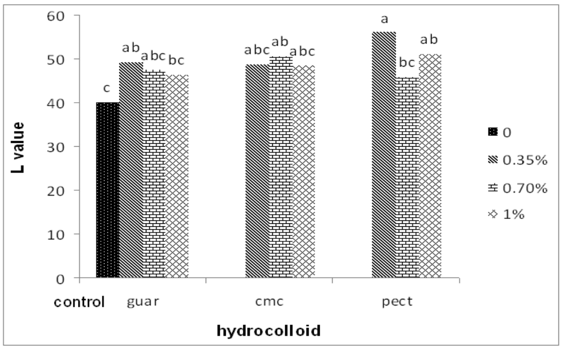
In general, color provides a useful measurement for determining changes due to processing and possible acceptability by consumers. The effects of edible coatings on color of donuts are shown in Fig. 5 and table 3. In the present work, the application of the coatings with different concentrations increased the L value of the donut compared to the control treatment (Fig 5 (A)). In addition, the edible coatings slightly enhanced the yellowness of donut, which was reflected in higher b values (blue to yellow) (Fig. 5 (C)). However, Garcia *et al.* (2002) reported no significant changes in the color of potato chips due to the application of an edible coating, which might be related to the nature of the product or differences in the frying process. The color change in fried donuts might be caused by non-enzymatic browning during heating due to Maillard reactions as a result of the interaction of an amine group with reducing sugars. Color change (ΔE values) during frying of donut coated with different gums was significantly less than the ones coated with control batter. The ability of gums to bind moisture prevents dehydration and inhibits the Maillard browning reaction. The lighter color can also indicate that the product absorbed less frying oil. Therefore, it was not surprising that gums provided significantly lower color changes to products (Akdeniz *et al*, 2006).

Table 3. Analysis of variance of crust color of donut.

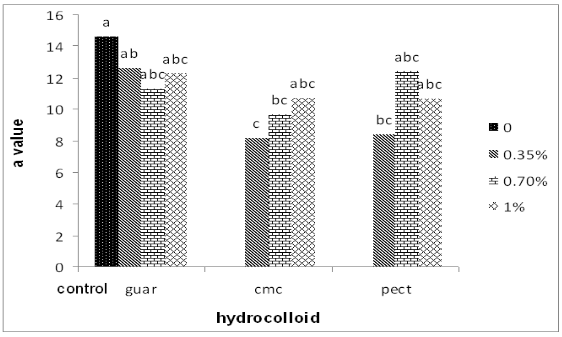
Source of variation	df	Mean Square			
		L	a	b	ΔE
Control versus the rest	1	184.831**	37.876**	34.980 **	213.683 **
gum	2	17.194	9.836	1.636	22.260
concentration	2	19.390	3.993	1.868	27.233
Gum× concentration	4	19.643	4.044	4.287	24.331
Error	10	13.123	3.0572	2.7003	13.170
CV (%)		7.011	13.521	6.074	37.008

*, **: Significant at 1% and 5% probability level, respectively Color Measurement.

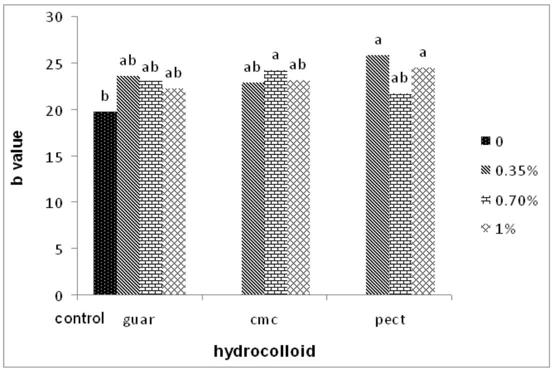
Effect of gum coating was not significant ($P > 0.05$) on color changes during frying time. Tan and Mittal (2006) found that higher initial moisture content resulted in lighter surface color of donuts.



(A)



(B)



(C)

Fig. 5. Effect of type and concentration of Gum on (A) L; (B) a; (C) b color values of donut.

Means followed by the same letter are not significantly different at P=0.05.

Sensory properties

Sensory quality is an important aspect in considering the overall acceptability of food product. Deep fat frying is widely used in industrial preparation of foods, because consumers prefer the taste, appearance, and texture of fried food products (Pahade *et al*, 2012). ANOVA showed differences between coated and uncoated donuts in terms Overall appearance, the appearance of crust, Color crust of were significantly ($P < 0.01$)identified by panelists but other characteristics had no significant differences in donuts.Finally, evaluators did not recognize any significant differences between coated and uncoated donuts. (table4)

Table 4. Results of Friedman test.

		Mean Square		
Trait	**Number**	**Chi-Square**	**df**	**Significant level**
Overall appearance	7	22.28	9	0.008
The appearance of crust	7	26.08	9	0.002
Color crust	7	22.10	9	0.009
Color cure	7	12.41	9	0.191
Tissue	7	10.28	9	0.328
Taste	7	8.76	9	0.459
Smell	7	10.42	9	0.317
Overall acceptance	7	12.83	9	0.170

Conclusion

Donuts are fried delicious snacks with high energy value that could be a primary consideration for time-pressed consumers. It represents 8% of total in-store bakery sales, over $3 billion per year. However, donuts have taken a bit of a hit recently as health-conscious consumers are becoming more aware of oil content, which has been linked to increased risk of heart disease. The use of hydrocolloids to decrease oil absorption in donut was studied. By suitable selection of edible films it is possible to control moisture and fat transfer between the frying medium and the food. Deep-fat fried donut having less oil and a high volume and moist on the inside but crisp on the outside are desirable. Most of the tested coatings decreased the fat uptake but also decreased the water reduction during frying of the product. All samples were accepted by the panelists, although color differences between coated and uncoated samples were detected by instrumental analysis. Highest score for overall appearance and color of the crust for treatment of pectin 0.7and 1% respectively. Guar, carboxymethyl cellulose and pectin 1%, 1% and 0.7% concentrations of each type was chosen as the best. The pectin 0.7% for the highest reduction in oil uptake, higher moisture and least changes in color as the hydrocolloid coating was diagnosed.

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