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ORIGINAL ARTICLE

Effect of Edible Coatings (Xanthan gum and Carob gum) on the Physicochemical and Sensory Properties of French Fries Potatoes

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Abstract

In the present study, French fries potatoes were coated with combination of xanthan gum and carob gum or each of them separately at different concentrations of 0.25, 0.5, 0.75 and 1.5%(w/v) beside the control sample which was considered without coating. Samples were fried at 180℃ for 6 min. The percentage of hydrocolloids coating, moisture content, oil uptake, textural characteristic (hardness index), frying efficiency, colorimetric characteristics (brightness, redness and yellowness indexes plus color difference) and sensory evaluation (Flavor, aroma, appearance, color and overall acceptance) of potato strips were measured. The results indicated that when the hydrocolloids coating of potato strips applied, the moisture retention capacity increased, oil uptake decreased, frying efficiency increased, brightness index reduced and redness/yellowness index increased. Also by increasing the hydrocolloid initial concentration over 1%, sensory evaluation of the samples decreased. Sensory and physiochemical properties significantly decreased in the control sample ($p \geq 0.05$). As a final point, the sample contained 0.25% carob gum and 0.75% xanthan gum was introduced as superior treatment.

Keywords: French fries potatoes; Carob gum; Xanthan gum; Oil uptake; Sensory evaluation

Introduction

Importance of cardiovascular disease has let the consumers to prefer low-calorie meals. This subject has made an approach to the processes and substances which could reduce oil absorption while preserves the quality of the product (Bouchon et al., 2001, 2003). A large number of compounds and additives can be used for the aforementioned purpose, among them hydrocolloids can be considered as a main group (Dipjyoti Saha and Suvendu Bhattacharya., 2010). Deep-fat frying is a complex unit operation involving high temperatures, significant microstructural changes both to the surface and the body of the chip, and simultaneous heat and mass transfer resulting inflows in opposite directions of water vapor (bubbles) and oil. Heat transfer leads to proteins denaturation, starch gelatinization, water evaporation, crust and brittle shell formation with favorable color (Sanz et al., 2007).Throughout the frying process, food will lose its moisture in order to oil will be replaced (Fritsch. 1981, Lisinska and Leszcynski. 1989, Garcia et al., 2002). Debnath et al., (2003). Many factors can impact on oil absorption including temperature, time of frying, pretreatments such as blanching and composition of potato (e.g. fat, solid, protein, and moisture content) (Blumenthal and Stier., 1991).

According to Dietary Guidelines (USDA and USDHHS, 1995), the total fat intake should be less than 30% daily energy intake and saturated fat intake also should be less than 10% and monounsaturated and polyunsaturated fats should contain at least two-thirds of the total daily fat intake. It has been determined that coating of potatoes with hydrocolloids reduces oil absorption (Funami et al., 1999, Khalil., 1999, Garcia et al., 2002, Susanne et al., 2002).

Hydrocolloids have been using as a multifunctional additive in food processing. They are added to control and improve functional properties like viscosity, water binding capacity, emulsion stability and oil absorption (Ang., 1993, Williams and Mittal., 1999). Hydrocolloids have become very popular in recent years and different types of them such as almond gum (Bouaziz et al., 2016), aloe vera gel (Abbasi et al., 2015), Salep and Basil Seed Gum (Karimi and Esmaeilzadeh Kenari., 2015), agar, carboxymethylcellulose, hydroxymethylcellulose, xanthan, carrageenan and alginate (Varela Fiszman., 2011) were studied.

It has been well documented that edible coatings applied to food substrates before frying aid in limiting moisture and oil transfer during frying (Mallikarjunan et al., 1997; Holownia et al., 2000; Albert and Mittal, 2002; Park and Chinnan, 1995). It is the proven ability of these films and coatings to limit moisture transfer that may be the key to the production of crispier fried products. Furthermore, edible films and coatings, by acting as barriers to control the transfer of moisture, oxygen, carbon dioxide, lipids and flavor compounds, can prevent quality deterioration and increase the shelf life of food products (Ballard., 2003).

In the present study the effect of hydrocolloids coating (xanthan gum and carob gum) on potato strips during deep-fat frying was studied in order to investigate oil uptake, frying efficiency, moisture content and sensory properties.

Methodology

For this experiments, Agria potatoes (*Solanum tuberosum L.) were purchased from vegetable research farm located in Varamin Islamic Azad University of Iran. They were stored in the dark place at 7 ℃ with 93-95 % relative humidity and a week before experiments they were transferred to ambient temperature. The hydrocolloids and all chemicals (*Solvent petroleum ether, Sodium thiosulfate, Potassium iodine, Hydrochloric acid with a concentration of 4 mol/L- and ethanol) *were purchased from Merck Chemistry Co, in Germany. Frying oil (mixture of soybean, Cottonseed and sunflower oil) was from Bahar Oil Factory (Tehran, Iran) and stored -22 ℃ prior to the experiments.*

Preparation of Hydrocolloids Solutions

Xanthan gum, carob gum and mixed solution of them in respective concentrations of 0.5, 0.75, 1 and 1.5 %(w/v) were prepared. The hydrocolloids were dissolved in deionized water at 25 °C. Each solution was stirred for 30 minutes to reach a Homogeneous solution (Ultra-Turrax homogenizer, Germany). In order to complete hydration they were stored at the ambient temperature for a night.

Preparation of French Fries Potato

In this study, potato tubers were peeled by hand and sliced into $1\ cm \times 1\ cm \times 6\ cm$ strips by French fry cutter (HALLDE RG 250, Sweden). After washing with cold water, they were immersed in hydrocolloid solution including xanthan gum and carob gum each one separately and mixed solution of the both at different levels of 0.25, 0.5, 0.75 and 1.5% (w/v) at ambient temperature for 2 min. Afterward, samples were drained and dried by a convection oven (Memmert UF55/UN55, Germany) at 150℃ for 5 min in order to decrease surface water. In addition, Control samples was considered uncoated. Frying was carried out in deep fat fryer (*Delonghi, Italy).* Potato strips were fried at 180℃ for 6 min in the frying oil. The temperature of 180℃ is usually selected as a common frying temperature in industry. (Pedreschi & Moyano., 2005). All fried samples were cooled to room temperature prior to being analyzed shown in **Table 1**.

Table 1. Treatments of study

Treatments	Xanthan gum (%)	Carob gum (%)
Control (C)	0	0
A_1	0.75	0
A_2	0.75	0.25
A_3	0.75	0.5
A_4	0.75	0.75
A_5	1.5	0
A_6	0	0.75
A_7	0.25	0.75
A_8	0.5	0.75
A_9	0.75	0.75
A_{10}	0	1.5

Moisture Content and Oil Uptake Measurement

The moisture content of samples was determined by calculating the weight loss of the fried potatoes upon drying in a convection oven at 105 °C until reaching to the constant weight. Samples were weighted every 5 min till the constant weigh were achieved. In order to determine Oil uptake, Soxhlet method was used. For this purpose, a certain amount of samples was measured (5 g) then oil extraction was performed using petroleum ether as solvent for 6 hours. (AOAC, 2005. Rimac-Brnci *et al*., 2004. Pardun, 1969). In order to evaluate of oil content and moisture content of fried potato strips using the method Susanne and Gauri., 2000 and the amount of oil content and moisture content due to coating were calculated as follow:

$$Oil\ content = [\frac{\text{amount of oil in coated strips} - \text{amount of oil in uncoated strips}}{\text{amount of oil in uncoated strips}}] \times 100$$

$$\text{Moisture content} = \frac{\text{amount of moisture in } un\text{coated strips} - \text{amount of moisture in coated strips}}{\text{amount of moisture in uncoated strips}} \times 100$$

Reduction of oil absorption due to coating was calculated as follows :(Keller et al., 1990)

$$Oil\ uptake = [\frac{\text{amount of oil uptake in coated strips} - \text{amount of oil uptake in uncoated strips}}{\text{amount of oil uptake in uncoated strips}}] \times 100$$

Coating Measurement

As an explanation it can be said that the "percentage of coating" is amount of hydrocolloids adhering to the surface of potato strips during immersion in suspension before frying process. It can be calculated as the difference of the weight of coated potato strips and the weight of uncoated strips shown in the following equation: (Akdeniz. 2004)

$$\% \text{ Coating} = (C-I) / I * 100$$

Where C: weight of coated potato stripes (g)
I: initial weight of uncoated potato stripes (g)

Colorimetric Measurement

The color parameters (Hunter L, a, b) were evaluated with a Konica Minolta Chroma Meter (CR-400, Japan). In order to express the color of the Hunter parameters in terms of black to white the parameter of L^* (Lightness), for greenness to redness the parameter of a^*(redness) and for the blueness to yellowness parameter of b^*(yellowness) were used. Before using the hunter lab, each of the three color parameters was calibrated with a White ceramic plate. (Yam *et al*., 2004). L_0^*, a_0^*, b_0^* are color parameters before coating. Color difference (ΔE) can be calculated as shown in the following equation:

$$\Delta E=\sqrt{(L^*-L_0^*)^2+(a^*-a_0^*)^2+(b^*-b_0^*)^2}$$

Textural Property Measurement

In order to measure the textural property of potato strips (hardness), the texture analyzer (TA-XT-plus, England) was used. A/WEG probe with diameter of 0.2 mm along with 10mm/s speed was applied. The maximum penetration resistance (F_{max}) (gram of force/25 kg cell) was measured.

Evaluation of Potato Frying Efficiency

Frying efficiency of potato strips was measured by calculating the weight of coated fried potato strips relative to the weight of raw samples after coating which was obtained as follows :(Akdeniz.,2004)

% frying efficiency: (CW/C) ×100

Where CW: Weight of coated fried potatoes
C: Weight of coated raw potatoes strips

Sensory Evaluation

Sensory evaluation of French fries potatoes were performed by ten trained panelists. Randomly, coded samples were served to panelists separately. Five sensory features were assessed (appearance, color, aroma, flavor, and overall acceptance) using 5-point hedonic scale. For each feature 5=excellent and 1=extremely poor.

Statistical Analysis

Sample analysis was performed using a completely randomized design with Minitab software (version 17). The level of statistical significance was determined at 5% ($p \leq 0.05$). If a significant difference was observed, treatments were compared by Duncan's multiple comparison test. All analytical measurements were done in triplicate.

Results and Discussion

Effect of Coating Percentage

In this experiments, coating percentage was between 54 to 68%. (**Table 2**). Where the highest value was belonged to the mixed solution of 0.75% xanthan gum and 0.75% carob gum. This was due to higher viscosity and solid content in which may reflect on greater weight increase compared to other treatments. In general, the amount of coating will be increased as the concentration of gums raised, but this increase is not uniform and linear (Dogan and Kayacier., 2004)

Table 2: Comparison of the average coating percentage

Treatments	Percentage of coating
Control (C)	0^{e}
A_1	54 ± 0.03^{d}
A_2	57 ± 0.01^{c}
A_3	60 ± 0.02^{b}
A_4	65 ± 0.01^{ab}
A_5	63 ± 0.02^{ab}
A_6	54 ± 0.03^{d}
A_7	59 ± 0.01^{c}
A_8	62 ± 0.02^{ab}
A_9	68 ± 0.01^{a}
A_{10}	65 ± 0.02^{ab}

Numbers with the same letters do not differ statistically ($p\leq0.05$)
The data was mean ± standard deviation of three replicates.

Effect of Coating on Oil Uptake and Moisture Content

The effect of various hydrocolloids on reducing of oil uptake during frying is shown in **Figure 1**. The results have shown that immersion in 1.5% hydrocolloid solution had a remarkable impact on oil uptake ($p\leq0.05$). This can be due to limiting moisture and oil transfer by edible coatings during frying. It can be noted that the both of hydrocolloids were effective in order to decline oil uptake however the highest influence was referred to solution contained 1.5% hydrocolloid which followed by the mixed solution of 0.75% xanthan gum and 0.75% carob gum (Samples A_4 and A_9). In addition, the samples in which contained only xanthan gum or carob gum (A_1 and A_6) indicated the lowest effect ($p\leq0.05$). The highest oil absorption was belonged to the control sample. Therefore, potato strips can be treated by immersion in the hydrocolloid solution above 1% before frying in order to reduce oil absorption notably. The result was accordance with Rimac-Brnci *et al*., 2004

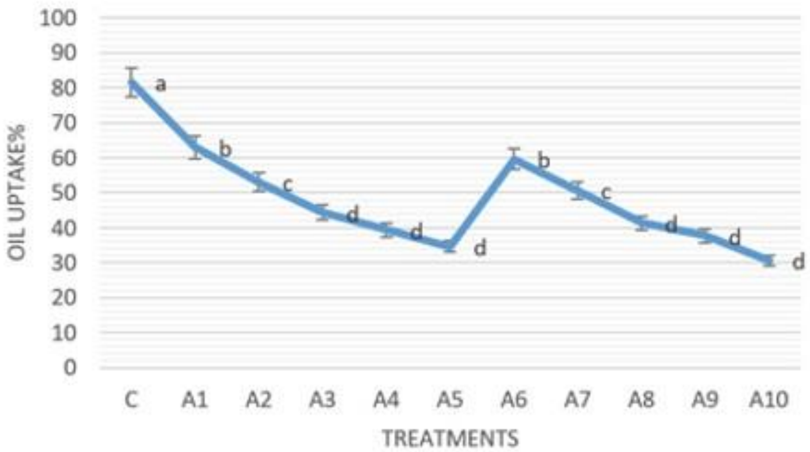

Figure 1. Effect of hydrocolloid addition on oil uptake during frying

Moisture content can be modified by applying hydrocolloid coating on potato strips before frying. However, it can affect the quality of the final product. (Tajner-Czopek et al., 2007). The results indicated that the control sample had lowest moisture content (53%). Moisture content of coated samples with either xanthan gum or carob gum at level of 1.5% was higher than those in which were treated by combination of gums. However, when percentage of coating was above 1%, there was no significant difference between moisture content in the samples ($p\leq0.05$). In general, the process of hydrocolloid coating provided a greater resistance to water vapor migration compared to uncoated sample. This phenomenon could be due to higher water binding capacity of hydrocolloids. Similar results were obtained by other researchers. (Bouaziz et al., 2016, Karimi and Esmaeilzadeh Kenari .,2015, Shaker., 2015)

Effect of Hydrocolloids Coating on Color

One of the most important factors in acceptability of fried products is the appearance. The process of hydrocolloids coating reduces the brightness factor and increases the amount of redness and yellowness index of the product in which is due to the fact that frying at high temperatures causes the caramelization of hydrocolloids coating and the color of the samples become dark and unpleasant. Therefore, by increasing the hydrocolloids coating, the rate of caramelization rises significantly and as a result redness index (* a) increases while brightness index (* L) declines notably.
The effect of various hydrocolloids coating on the color of potato strips was revealed in **Figure 2** and **Figure 3**. According to the obtained results, Lightness index (L *) of raw samples in which were coated with carob gum was higher than those were coated with xanthan gum ($p \leq 0.05$). Before frying, the highest Lightness index was belonged to the control sample and the lowest value was referred to potato strips contained 1.5% hydrocolloids concentration. However, after the frying process, the control sample was the lowest Lightness index but the highest value was belonged to the mixed solution of 0.25% xanthan gum and 0.75% carob gum (A_7).

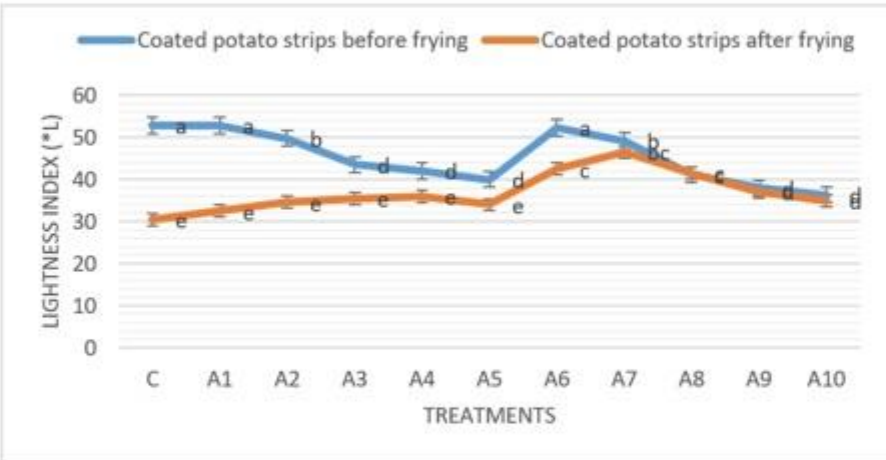

Figure 2. Effect hydrocolloids coating on Lightness index during frying

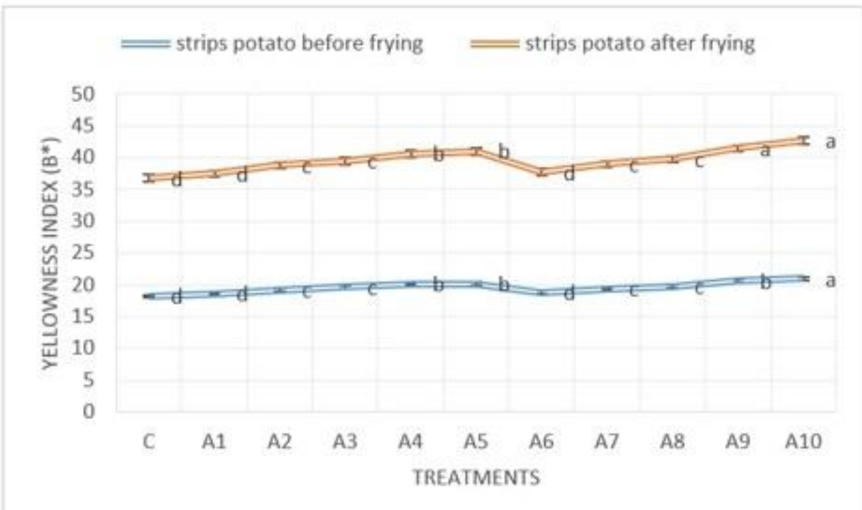

Figure 3. Effect hydrocolloids coating on Yellowness index during frying

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Yellowness index (b^*) of potato strips was investigated as well. According to the results, yellowness index (L *) of raw samples in which were coated with carob gum was higher than those were coated with xanthan gum ($p \le 0.05$). Before frying, the highest yellowness index was belonged to the potato strips with 1.5% hydrocolloids concentration and the lowest value was referred to the control sample. But during the frying process, highest changes in yellowness index occurred in the mixed solution particularly in suspension which contained carob gum ($p \le 0.05$). In addition, evaluation of redness index (a*) of potato treatments showed that the redness index (a*) significantly boosted by increasing the rate of hydrocolloids coating. The lowest and highest redness index (a *) were belonged to the control sample(C) and treatments had 1.5% hydrocolloids concentration (A_5 and A_{10}) respectively ($p \le 0.05$).

Evaluation of Color Difference Test (ΔE)

According to the consequences, the color difference index (ΔE) was significantly enhanced by increasing the rate of hydrocolloids coating ($p \le 0.05$). The lowest and highest color difference index (ΔE) were referred to the both control sample(C) and potato strips coated with 1.5% hydrocolloids concentration (A_5 and A_{10}) respectively. In general, samples contained carob gum comparing to those with xanthan gum had lower color differences index (ΔE) during frying process ($p \leq 0.05$).

Evaluation of Textural Analysis of French Fries Potatoes

Fried product texture is one of the most qualitative features of the product. There is a very clear difference between the inner and outer texture of fried potato strips. The inner texture should be soft and dense, while the outer crust should be crispy (Asadi., 2010). In this study, it was observed that the hardness index of samples was increased along with increasing the hydrocolloids coating. Therefore, an increase in amount of hydrocolloid coatings can have undesirable effects on texture and consumer acceptance. The highest hardness index was belonged to those in which were coated by either 1.5% Carob gum or xanthan gum. ($p \le 0.05$). The lowest was referred to the control sample. Similar result was obtained by Esmaeilzadeh kenari et al (2016) applied locast bean and Avicennia marina seed gum.

According to others studies, the final texture of the fried product is negligibly affected by the composition of the foodstuff. The reaction between proteins, starch and its compounds (amylose and amylopectin) are important for the final product quality.Therefore, it can be said that carob gum, xanthan gum or mixture of them caused texture stiffening in order to increase the force required to cut the fried potato strips in which was probably due to the reaction of the gums with the compounds of the cell wall of potatoes.(Olewnick, and Kulp.,1993. Rovedo et al.,1999)

Results of Frying Efficiency

Since the frying efficiency indicates the weight of the final product, therefore, according to the results, it can be said that the weight of final products in which were coated by edible hydrocolloids greater than those were uncoated. This was due to the ability to maintain moisture content by the gums. Therefore, treatments with 1.5% gums (A_5, A_{10}) had the highest frying efficiency and the control sample(C) showed the lowest value. It was also observed that treatments coated by xanthan gum had a higher frying efficiency than those in which were coated with carob gums. ($p \leq 0.05$) This phenomenon is related to the type of the hydrocolloid and their water holding capacity, which can prevent the water from evaporation and thus result in higher frying efficiency. (Akdeniz., 2004., Akdeniz et al., 2006. Karimi and Esmaeilzadeh Kenari., 2015).

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Result of Sensory Evaluation

Results showed that there was no substantial difference between the mean scores of coated fried potatoes (0.75% carob gum and 0.75% xanthan gum) and the control sample. ($p \leq 0.05$). However, in terms of all sensory parameters in this study, the treatments with 0.75% carob gum and 0.5% xanthan gum as well as 0.5% carob gum and 0.75% xanthan gum had the highest score among all coated treatments. The score of sensory parameters were significantly reduced by increasing the rate of hydrocolloids coating over 1 %. In terms of overall acceptance, there was a significant differences between the mean scores of treatments in which was associated with the amount of hydrocolloids coating as well as the type of the gums. ($p \leq 0.05$) .According to the panelists, the overall acceptance rate reduced significantly by increasing the amount of hydrocolloids coatings. (Fig 4)

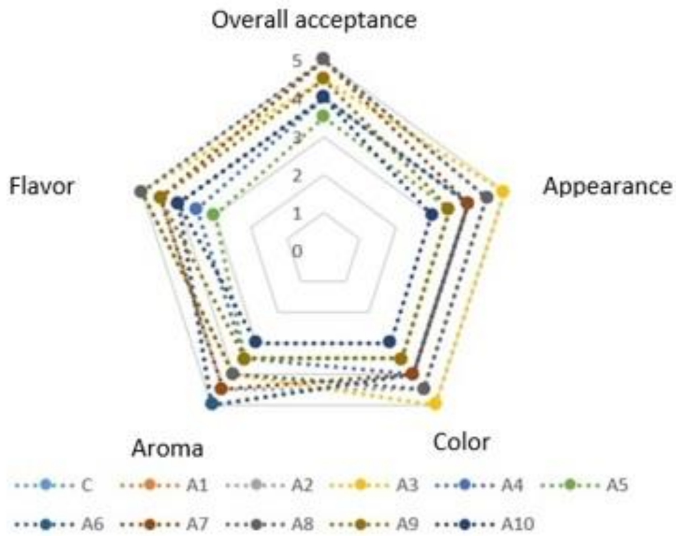

Figure 4. Effect of hydrocolloid addition on sensory properties during frying

Conclusion

The results of this study showed that the hydrocolloid coating due to its preventing properties could reduce the loss of moisture content. Considering the role of water content of samples in oil uptake percentage, the oil content in all coated samples comparing with uncoated sample decreased notably. Among the studied gums, the best result was obtained for the sample contained 0.25% carob gum and 0.75% xanthan gum. Consequently, these edible gums can be introduced as an inexpensive and suitable coating agent to reduce oil uptake in French fried potatoes.

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