Effects of batters containing different gum types on the quality of deep-fat fried chicken nuggets

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Abstract: The effects of various gum types [hydroxypropylmethylcellulose (HPMC), guar gum, xanthan gum, gum arabic] on the quality of deep-fat fried chicken nuggets were studied. Chicken samples, 0.04 m in diameter and 0.015 m in thickness taken from the breast portion, were coated with batters composed of a 3:5 solid to water ratio by immersion. The solid content of batter formulations contained equal amounts of corn and wheat flours, 1.0% gum, 1.0% salt and 0.5% leavening agent. As control, batter without gum addition was used. Samples were fried at 180 °C for 3, 6, 9 and 12 min. The hardness and oil content of the chicken nuggets increased whereas the moisture content decreased during frying. HPMC and xanthan gums reduced oil absorption significantly compared with other gums and the control. When gum arabic was added to the batter formulation, a product with the highest oil content and porosity was obtained. © 2005 Society of Chemical Industry

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INTRODUCTION

Batters are liquid mixtures comprised of water, flour and seasoning into which food products are dipped prior to frying. Coatings are commonly used in deep-fat frying since they improve appearance, flavor and texture by reducing dehydration, aiding browning and giving a crisp texture to the fried parts.1 A recent trend in reducing the fat content in fried foods is the development of batter formulations with specific ingredients. The batter coating apparently functions to reduce moisture loss during frying, which, in turn, reduces oil absorption.2

A typical tempura batter consists of wheat flour, corn flour and leavening agent as critical ingredients to which other flours, hydrocolloids, colorants and flavorings can be added as optional ingredients.3 Because of their higher water-binding capacities, hydrocolloids develop consistency in batter systems, helping to trap gas evolved by the fast action of leavening agents.4 This results in a higher volume and improves the texture of the fried products. Food gums, as specific ingredients, are often used for their texturizing capabilities. Guar gum is used as a water binder, stabilizer and viscosity builder in several food systems including canned foods, desserts, dressings and bakery products.5 Gum arabic, owing to its solubility in hot or cold water, is the least viscous of the hydrocolloids. Xanthan gum is readily dispersed in water, hence high consistency is obtained rapidly in both hot and cold systems. The high apparent viscosity of the formulation results in highly stable suspensions, emulsions and foams.6 Hydroxypropylmethylcellulose (HPMC) is a hydrocolloid that gels when heated and returns to its original liquid consistency when cooled. This property makes it suitable to be used in fried foods as a batter ingredient since it reduces oil uptake and moisture loss during deep-fat frying of foods.5 Most food gums have a significant effect on the available free water and the rheology of liquid batter systems. Retaining moisture, forming films, contributing to freeze–thaw stability and providing mild surfactant properties, gums can enhance quality of fried food products.7

Cellulose derivatives have been used as hydrocolloids in batter formulations to reduce oil uptake in deep-fat fried products in various studies.8–14 The oil and water barrier properties of different hydrocolloids [methylcellulose (MC), gelatine, gellan gum, κ-carragenan, locust bean gum, microcrystalline cellulose and pectin] and proteins (sodium caseinate, soy protein isolate, vital wheat gluten, whey protein isolate) were compared during frying of a cereal product and it was observed that soy protein isolate, whey protein isolate and MC were the best materials to reduce oil uptake during frying.8 The fat contents of fried batter coatings were reduced significantly when 1% powdered cellulose was incorporated into the batter.9 In another study, HPMC coating reduced the oil absorption in the surface layer and core region of chicken nuggets as compared with uncoated nuggets.
Effects of coating of french fries with different hydrocolloids as a single and double layers were studied. Application of a second layer of coating provided better quality products. When carboxymethylcellulose (CMC), pectin or sodium alginate was used as a second layer of coating, CMC was most effective in reducing the oil content. HPMC was found to be more effective as an oil barrier than powdered cellulose during frying of doughnuts and falefel balls.

The number of studies on the effects of xanthan, guar and arabic gums used in batter formulations on the quality of deep-fat fried products is limited in the literature. Therefore, in this study it was aimed to compare the effects of xanthan, guar gum, gum arabic and HPMC on the quality of deep-fat fried chicken nuggets. This study contributes findings on not only the oil- and moisture-binding ability of these gums but also their efficiency in the development of color, volume, porosity and hardness of the battered product during frying.

MATERIALS AND METHODS

Materials
Guar gum, gum arabic and xanthan gum were obtained from Aldrich Chemical (Steinheim, Germany) and HPMC (Methocel F, 28% methoxyl substitution, 5% hydroxypropyl substitution) was provided by Dow Chemical (Midland, MI, USA).

Wheat flour (Söke Değirmencilik Tekstil San. ve Tic AŞ, Aydın, Turkey), corn flour (Pinar Un, Unlu Mamuller AŞ İzmir, Turkey), sunflower oil (Bizim, Bazar Gıda ve Kimya San ve Tic AŞ, İstanbul, Turkey), leavening agent (NaHCO3) and chicken breast used for the experiments were obtained from the local market.

Sample preparation
Breast portions of chicken were placed in a deep-freezer at −10°C for up to 2 months prior to use. Frozen samples were thawed at 10°C for 4 h in a refrigerator before the experiments commenced. Samples 0.04 m in diameter and 0.015 m thick were cut by using a manually operated cutting device. The radial direction of nuggets was parallel to the fibres. Each sample was weighed, before dipping into batter, to have a uniform range of 0.014 ± 0.002 kg.

Batter formulations were composed of a 3:5 solid to water ratio. The solid content of batter formulations contained equal amounts of corn and wheat flours (48.75 g each), 1.0% gum, 1.0% salt and 0.5% leavening agent. Batter without gum addition was used as a control. Lack of gum in the control formulation was compensated for by a corn and wheat flour mix. The batters were prepared by mixing the dry ingredients with water at 25 ± 1°C using a mixer at the lowest speed for 30 s (ARK55 MS, Arçelik, İstanbul, Turkey). Chicken samples were immersed individually in the batter suspensions for 10 s and allowed to drip for 30 s.

Coating mass was determined from the decrease in weight of the batter suspension after coating of a chicken piece. Batter pick-up was calculated by taking the ratio of the coating mass of batter to the weight of the non-coated nugget and multiplying by 100.

Frying
Samples were fried at 180°C in commercial bench-top deep-fat fryer (Moulinex, Bagnolet, France) containing 2.5 l of sunflower oil. A copper–constantan thermocouple was connected to the fryer to control the temperature. Four pieces were deposited in the frying oil each time. Samples were fried for 3, 6, 9 and 12 min. After each frying batch, the oil was filtered to remove batter debris and the oil was replaced after 6 h of frying.

Analysis of samples
For moisture determination, the whole fried samples were dried in a forced convection oven at 105°C until constant weight.

The oil content of the fried samples was determined by Soxhlet extraction of the sample with n-hexane for 6 h.

Bulk volume was measured by the water displacement method. The platform scale of Mohsenin was used for this purpose.

The solid volume, which excludes the volume of air inside the product, was determined by the gas displacement method with a nitrogen stereopycnometer (Quantachrome, Boynton Beach, FL, USA).

Porosity, defined as the volume fraction of the air or the void fraction in the sample, was estimated using bulk and solid densities of the sample.

Hardness of the fried samples was measured 45 min after frying using a universal testing machine (LR30K, Lloyd Instruments, Fareham, Hants, UK). A load cell of 50 N was used. A conical probe (\(D = 0.04\) m, \(H = 0.05\) m) was attached to the crosshead for penetration tests. The peak force required for 25% penetration of the conical probe into the fried sample, set at a speed of 55.0 mm min\(^{-1}\), was recorded.

The color of the fried chicken samples was measured using a CR-10 color meter (Minolta, Osaka, Japan) using the CIE Lab \(L^*\), \(a^*\) and \(b^*\) color scale. Color readings were carried out at room temperature on three different sections of each sample and the mean value was recorded. The total color change (\(\Delta E\)) was calculated from the following equation in which the white color of BaSO\(_4\) was used as the reference point:

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\Delta E = [(L^* - L_{BaSO_4})^2 + (a^* - a_{BaSO_4})^2 + (b^* - b_{BaSO_4})^2]^{1/2}
\]

Statistical analysis
Each analysis was repeated at least four times under each set of experimental conditions. The data were
Gum-added batters for chicken nuggets evaluated by using two-way analysis of variance (ANOVA) in order to determine the significant differences between the effects of gum types and frying times on the quality parameters of deep-fat fried chicken nuggets. If a significant difference was found, the treatments were compared by using Duncan’s multiple comparison test ($p \leq 0.05$).

RESULTS AND DISCUSSION

Figure 1 shows the effect of gum type on coating pick-up of chicken pieces. Xanthan, guar gum and HPMC were found to be significantly effective for batter pick-up. Gum arabic addition did not increase coating pick-up significantly. This might be due to its low apparent viscosity since it readily dissolves in water.

Figure 2 shows the effects of gum types on the moisture content of deep-fat fried chicken nuggets. All the gums used in this study except gum arabic were able to control moisture migration. Gum arabic dissolves in water whereas the other gums form dispersions. The high solubility of gum arabic in water may be the reason for its lack of ability in controlling moisture loss. The frying time had a significant effect on moisture content. In the initial stages of frying the most effective hydrocolloid was HPMC in terms of moisture retention. HPMC gum is the key ingredient for designing barrier films since it provides film-forming properties and thermal gelation ability.18

The effect of gum type on oil content is shown in Fig 3. There were statistically significant differences between the effect of frying time on oil content as in the case of the variation of moisture content. All of the gums were significantly effective in reducing the oil content of the deep-fat fried chicken nuggets except gum arabic. HPMC and xanthan gum were found to have the same effect on oil uptake of chicken nuggets, with the lowest values. A major functional property that is useful in reducing the oil content in fried foods is thermal gelation. HPMC gum is a hydrocolloid that forms thermal gels. The methyl groups in HPMC undergo intermolecular association with adjacent molecules above the gelation temperature. Therefore, above this temperature, consistency increases dramatically to the point where the gel is formed. This gel matrix affects the barrier properties and consistency at high temperatures, which explains the reduced oil absorption when HPMC was used in the batter formulation. The reduction of oil uptake in the case of xanthan and guar gums may be related to their viscosity-building effects. The highest oil content was observed when gum arabic was added to the batter formulation as compared with the control and other gum-added batters. This might be due to its low apparent viscosity, which could not provide an efficient barrier for oil uptake. This is confirmed by its lowest coating pick-up (Fig 1).

The moisture evaporates at the product surface owing to the partial vapor pressure difference between the product and oil during frying. Oil fills the voids
left by water vapor at the same time. The high oil content of product when gum arabic was used was an expected result since gum arabic was not able to control moisture loss (Fig 2).

Addition of gums to the batter formulations was significantly effective with respect to the bulk volume of the fried nuggets as compared with control batter (Fig 4). Xanthan, HPMC and guar gum were found to provide the highest volume to the nuggets. Gum arabic addition to the batter formulation increased the bulk volume as compared with the control but its effect was smaller than those of the other gums. This may be explained by the difference in the film-forming abilities and gas-holding capabilities of the different gums. The thermal gelation characteristic of HPMC contributes added strength to the batter and increases gas retention during frying. It is known that xanthan gum is mostly preferred for providing highly pseudoplastic and elastic gels to the solutions. Xanthan and guar gums develop consistency that helps the batter to trap gas. This provides a higher volume to the fried product. Frying times were not significantly different with respect to their effect on bulk volume.

Control batter and HPMC-added batters were not found to be significantly different in affecting the porosity of the chicken nuggets (Fig 5). However, other types of gums were significantly effective with regard to the development of porosity of the samples. Gum arabic provided a relatively high porosity to the product, as expected, since it had the highest oil content during frying. Increases in both porosity and oil uptake during frying were reported previously. Frying time was significantly effective on porosity development. The lowest porosity was observed in nuggets fried for 6 min. The nuggets fried for 12 min were found to be significantly more porous than those fried for 3, 6 or 9 min.

Figure 6 shows the effect of gum type on the texture of fried samples. The peak force required for 25% penetration increased during frying. The hardness of the nuggets was significantly affected by the frying time. Control coating, guar and arabic gums had the same effect on the texture of the fried nuggets. HPMC and xanthan gum were found to provide a softer texture to the fried nuggets as compared with the control. It was previously reported that gums improved the texture of fried batters in terms of enhancing batter flexibility owing to their improved film-forming abilities.

The effects of gum species on the color of deep-fat fried nuggets are shown in Fig 7. Color development was lower as compared with the control when guar gum or xanthan gum was added to the batter formulation. This may be due to the dilution of the protein content of the flour mixture with the addition of these gums. Gum arabic was found to be the most effective gum with respect to color development by providing the darkest color to the fried sample. Gum arabic is known to have a protein portion in its composition, which may contribute to color development during frying. Dilution of protein concentration due to the replacement of 1% of wheat
and corn flour mixture was compensated with the protein content of gum arabic. Therefore, there was no statistically significant difference between the control and gum arabic-added batter with respect to color development. In addition, the amount of oil absorbed by the product during frying also affects the color of deep-fat fried chicken nuggets. Therefore, obtaining the darkest color in the presence of gum arabic was an expected result since it cannot control oil uptake efficiently. There were statistically significant differences among frying times in affecting color development.

**CONCLUSION**

Deep-fat fried chicken nuggets having less oil and a high volume and moist on the inside but crisp on the outside are desirable. Addition of gums to batter formulations was found to have a significant effect on the quality attributes of deep-fat fried chicken nuggets. Gum arabic can be considered the least acceptable gum since the use of this gum resulted in chicken nuggets having the highest oil content. When all the gums were compared in terms of reduction of oil absorption in chicken nuggets, HPMC and xanthan gum had the most significant effects. All gums were significantly effective on volume development within the fried product. Frying time was significantly effective for all of the quality parameters except bulk volume.

HPMC or xanthan gum can be recommended for use in batter formulations in deep-fat fried chicken nuggets in order to reduce moisture loss and oil uptake and provide voluminous nuggets. However, the textures of the products in the presence of these gums were softer than that of the control. In a further study, these results will be supported by sensory analysis.

**REFERENCES**


