ISSN 1330-9862 *original scientific paper*
(FTB-2635)

The Behaviour of Some Vegetable-Based Materials Used as Edible Coating on Chicken Nuggets

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Received: September 22, 2010
Accepted: February 22, 2011

Summary

In this study, chicken nuggets were predusted with zein or soy protein isolate (SPI) as the first coating. Next they were coated with 0.1, 0.2 or 0.3 % carboxymethylcellulose (CMC) batters as the second coating, and then breaded with bread crumbs. Finally, they were fried at 190 °C for 2, 4 or 6 min. Predusting materials were found to enhance some physical, chemical and sensorial properties of nuggets after frying. In particular, using SPI was more advantageous than zein. It increased penetrometer values and sensorial scores as it decreased moisture loss. The performance values of batter materials were improved compared to the control. Also, the yield, moisture rate, penetrometer and general appearance values decreased as the frying time increased. During this period, frying loss and fat absorption increased. Results showed that the best coating process was using SPI as predusting material, 0.1 % CMC for batter, and 2 to 4 min of frying time.

Key words: zein, soy protein isolate, carboxymethylcellulose, edible coating, chicken nugget

Introduction

Edible coatings, which enhance many desirable physical, chemical, and sensorial properties of food, have been widely used in food processing in recent years. These products play a major role in consumers' diets worldwide (*1,2*). Some consumers prefer their food cooked rare, whereas others like it well done. However, it is quite uncertain whether this food is healthy and in keeping with the nutrition rules or not. Fat absorption or moisture loss in foods can cause serious problems that can adversely affect the sensory and nutritive value of food. It can also critically affect product shelf-life. However, edible coatings may be used to reduce the fat absorption and moisture loss during deep frying. Physical properties like adhesion degree, and cooking could cause an increase in the food volume, which can increase the mass of the product. To obtain these properties, suitable coating materials, coating mix, and frying time are required. Also, appropriate coating materials can improve the sensory properties like colour, odour and taste (*3–5*).

Various vegetable proteins or gums are used in coating meat. Chicken or fish meat found on the market can be coated with materials like gluten, zein, soybean isolate, starch or cellulose derivates (*6,7*). However, there are limited studies about how different battering or breading processes can affect the characteristics of the coated meat obtained by new methods. In different studies, the coating process using vegetable-based materials was found to improve the product structure. Materials of either vegetable or animal origin are used together as a healthy form of diet (*5,8,9*). For example, hydroxypropylmethylcellulose (HPMC) and xanthan gum effectively and significantly reduced oil absorption in chicken nuggets. However, the use of gum arabic increased the oil absorption as compared to the control batter (*10*).

Ilter *et al*. (*6*) studied the effects of zein, soy protein isolate (SPI), guar gum, xanthan gum, corn flour, and soy flour on the quality of turkey nuggets. As a result, nuggets that were well coated were found to show a higher cooking yield and desired colour when they were coated with zein and SPI in the ratio of 73:27 as pre-

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dusting, guar and xanthan gums in the ratio of 0.3:0.1 as batter coating, and corn and soy flour in the ratio of 35:75 as breading.

Kılınççeker and Küçüköner (*5*) determined that utilizing coating with different proteins (zein, gluten, casein mix), different gums (guar, xanthan, locust bean) and different types of flour (wheat, corn) provided more resistance against fat absorption and moisture loss in chicken drumsticks during deep frying.

Kang *et al.* (*11*) reviewed the quality of pork patty coated with a pectin-based material containing green tea leaf extract powder. Lipid oxidation was found to decrease with this coating, and the coated patties contained higher moisture content than the controls.

Studies show that coating materials and processes are important factors in the production of coated products. Therefore, this study aims to evaluate the effects of coating with various predusting materials (zein, SPI) and the levels of CMC gum in the batter on some physical, chemical, and sensory properties of chicken nuggets. The best coating treatment and frying time are determined for chicken nuggets, and finally, an alternative production is presented for producers.

Materials and Methods

Materials

Chicken breasts were bought from Adiyaman Banvit Co. in Balıkesir, Turkey. Zein was purchased from Sunar Corn Products Co. (Adana, Turkey). SPI and CMC were obtained from Smart Chemical Co. (Izmir, Turkey). Flour, salt, and baking powder were obtained from the local grocery shops. Hydrogenated palm olein was the frying medium used (Frita, Unilever Co, Tekirdag, Turkey). Mini Fryer (model no. FF1024, Tefal, Shanghai, PR China) was used for frying. The capacity of the fryer was 1 L with thermostatic temperature control from 0 to 190 °C.

Methods

Chicken breast samples were cut into nuggets (2×2×3 cm) with a sharp knife and frozen at –18 °C for 24 h. Then they were thawed at 4–6 °C for 15 h. As the first step, the nuggets were individually predusted with the first coating material (zein or SPI). Then, they were dipped in 200 mL of batter that consisted of CMC (0.2, 0.4 or 0.6 g), wheat flour (47.8, 47.6 or 47.4 g), salt (1 g), baking powder (1 g) and distilled water, and allowed to drain for 5 min. Finally, they were breaded with bread crumbs. A total of 18 different coating combinations were applied. The samples that were only dipped in distilled water and breaded with bread crumbs were used as control. Following the coating process, the nuggets were fried at 190 °C. For each treatment, 6 nuggets were fried for different lengths of time (2, 4 or 6 min) in 1 L of fat.

Some properties of coating materials

The coating particle size was determined according to Elgun *et al.* (*12*) with a standard sieve. Absorption rate was ascertained according to Dogan and Unal (*13*). The moisture rate of the coating materials was determined gravimetrically by oven drying at (105±1) °C for 4–6 h. The protein rate of the coating materials was measured using the Kjeldahl method (*14*).

Viscosity measurement

Viscosities of the different batters were measured at (25±1) °C and 100 rpm using a digital rotary viscometer (RVDV-E, Brookfield, Middleboro, MA, USA). Spindle no. 2 was used in measurements.

Analysis of the coating material performance

Yield parameters were determined by measuring the mass of the raw chicken nuggets (X), the mass of the coated chicken nuggets prior to frying (Y) and the mass of the coated chicken nuggets after frying (Z). Calculations of the yield parameters were as follows (*15*):

$$\text{Adhesion degree}=\left(\frac{Y-X}{Y}\right)x100 \quad /1/$$

$$\text{Yield}=\left(\frac{Z}{X}\right)x100 \quad /2/$$

$$\text{Frying loss}=\left(\frac{Y-Z}{Y}\right)x100 \quad /3/$$

The moisture rate of the samples was determined at (105±1) °C for 4–6 h, and the fat rate was ascertained using the Soxhlet extraction method with *n*-hexane for 4 h, according to the guidelines proposed by the Association of Official Analytical Chemists (*16*). Moisture and fat rates were expressed as a percentage in coated samples (wet basis) after frying. Standard penetrometer (Yüksel Kaya Makina, Ankara, Turkey) equipped with a needle and a total of 100 g of lead was used to evaluate the hardness of the fried nuggets. Six nuggets were used for each replication. The needle was left to free fall from the same distance for each sample. The penetration depth was read in cm after 3 s of penetration. A panel of 10 semi-trained judges assessed the sensory properties using the hedonic scale for appearance, colour, odour, taste/flavour, and texture for acceptability. Different values in the scale indicated the following reactions: 1 extreme dislike, 2 very much dislike, 3 moderate dislike, 4 slight dislike, 5 neutral, 6 like slightly, 7 like moderately, 8 like very much, 9 like extremely (*17*).

The experimental design was a completely randomized factorial model (2×3×3), containing two types of the first coating materials, three types (0.1, 0.2 or 0.3 % CMC) of the second coating materials, and three variations (2, 4, or 6 min) of frying times, with two replications of each treatment. The data were subjected to the analysis of variance (ANOVA), and the results were expressed as the mean value±standard error (S.E.). The observed differences among samples were compared using Duncan's multiple-range test at $p<0.01$ and $p<0.05$ levels with the Statistical Analysis System Program v. 13.0 (SPSS, Chicago, IL, USA).

Results and Discussion

Physical and chemical properties of coating materials

Some physical and chemical properties of the coating materials are shown in Tables 1 and 2. Particle size distribution depends on the type of materials used. It affects the adhesion rate of the coating materials onto the meat surface. Particle size of the gum in the batter is also an important factor that influences the preparation of a homogeneous solution. Like in commercial practice, the texture of breading materials is classified as: coarse, medium, and fine (*18*). According to this classification, zein and bread crumbs were of medium, while SPI, CMC and wheat flour were of fine quality (Table 1).

The highest absorption rate was observed in CMC at 2198.9 % and the lowest absorption rate was in wheat flour at 59.68 %. The highest moisture rate was seen in wheat flour at 11.54 % while the lowest rate was in zein at 5.69 %. The highest protein rate was in SPI at 88.82 % and the lowest rate was in wheat flour at 10.45 % (Table 2). The batter viscosity in the 0.1 % gum content was 71.8 cP, in the 0.2 % gum its content was 109.01 cP and in the 0.3 % gum its content was 128.85 cP.

Performance values of coated nuggets

The ANOVA tests for the results of adhesion degree and yield values of the nuggets indicated significant effects of predusting and batter materials ($p<0.01$). Furthermore, the effects of frying times significantly influenced the yield values (p<0.0.5). In the ANOVA for frying loss values, the effects of predusting materials ($p<0.01$), batter materials ($p<0.05$), and frying times ($p<0.01$) were all significant.

Adhesion degrees and yields were found to be high in coated nuggets compared to the control samples. The highest adhesion and yield in the predusted nuggets were 26.30 and 113.76 %, respectively (with SPI coatings). Frying loss was low in the coated nuggets compared to the control. The lowest frying loss value seen in the predusted nuggets was 8.87 % (with SPI coatings, Table 3).

In the battered samples, the adhesion degree and yield values were high compared to the control, but the differences among the values for the materials were not statistically significant. In this group, the frying loss values were low compared to the control (Table 3).

The highest yield and the lowest frying loss were determined at 2 min. The yield decreased and the frying loss increased as the frying time increased (Fig. 1).

Table 1. Particle size distribution of coating materials

Material	*d*(<0.125 mm)/%	*d*(0.125–0.224 mm)/%	*d*(>0.224 mm)/%	*d*(>0.4 mm)/%
zein	0.51	9.28	23.87	66.29
SPI	5.80	44.99	49.21	–
CMC	63.25	36.21	0.54	–
wheat flour	7.27	53.95	38.78	–
bread crumb	6.20	22.12	33.74	31.90

Table 2. Some physical and chemical properties of coating materials

Material	Absorption rate/%	*w*(moisture)/%	*w*(protein)/%
zein	121.01	5.69	61.71
SPI	310.57	8.02	88.82
CMC	2198.90	7.25	–
wheat flour	59.68	11.54	10.45
bread crumb	216.67	6.74	12.11

Table 3. The effect of coating materials on the mean values of adhesion degree, yield and frying loss

Coating material	*N*	Adhesion degree/%	Yield/%	Frying loss/%
Predusting				
control	6	$(6.96\pm0.34)^{c}$	$(77.33\pm3.90)^{c}$	$(28.24\pm3.46)^{a}$
zein	18	$(21.54\pm0.60)^{b}$	$(90.49\pm2.50)^{b}$	$(20.32\pm2.15)^{b}$
SPI	18	$(26.30\pm0.31)^{a}$	$(113.76\pm2.03)^{a}$	$(8.87\pm1.19)^{c}$
Batter				
control	6	$(6.96\pm0.34)^{b}$	$(77.33\pm3.9)^{b}$	$(28.24\pm3.46)^{a}$
0.1 % CMC	12	$(22.95\pm1.17)^{a}$	$(98.39\pm4.10)^{a}$	$(14.06\pm2.89)^{b}$
0.2 % CMC	12	$(24.01\pm0.99)^{a}$	$(100.95\pm3.73)^{a}$	$(14.57\pm2.56)^{b}$
0.3 % CMC	12	$(24.82\pm0.30)^{a}$	$(107.03\pm5.24)^{a}$	$(15.14\pm2.82)^{b}$

N=total number of samples; different letters in superscripts represent statistical differences among samples

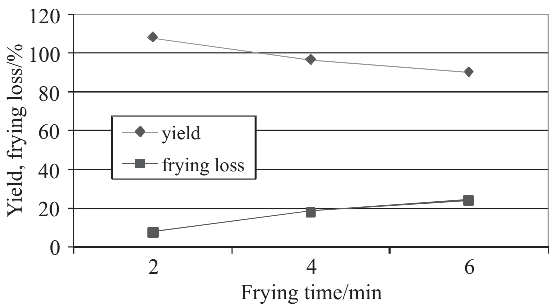

Fig. 1. The effect of frying time on the mean values of yield and frying loss in coated nuggets after frying

Evidently, SPI appeared to be a more adhesive material than zein, and its effect was more evident in the yield and frying loss than of zein. This is due to the smaller particle size and higher absorption rate and protein level of SPI, compared to zein. SPI adhered to nugget surface and degraded during the frying process, thus providing a film barrier that inhibited mass loss from the food substrate. Batter materials, however, were viscous solutions, consisting of polysaccharides (gum and flour) with fine particle size that provided an adhesive surface on the food for the bread crumbs. These materials become gelatinous because of the gums and starches in the flour, thus enhancing coating on the food surface. They provide an excellent barrier against mass transfer from the food matrix. They increase the adhesion degree and yield values, and lower the frying loss values (*2,8*). However, the decrease in yield and the increase in frying loss with the increase in frying time result from the cellular decomposition of the coating materials and meat. Mass transfer from the nuggets to the outside thus increased during deep frying (*5,10*).

To improve the coating properties like adhesion, coating components as proteins or hydrocolloids can be used (*19–22*). Maskat and Kerr (*23*) reported the highest coating adhesion in coatings that were formed from small particle bread crumbs, and the lowest in those made from large particle size bread crumbs. In another study, results showed that soy protein isolate had a better performance on chicken meat than whey protein isolate as coating material (*24*). Maskat *et al*. (*25*) determined coating pickup, coating loss, cooking yield and frying loss in chicken breasts coated with methyl cellulose (MC) solution. They observed a significant increase in the adhesion degree with the use of 1 and 2.5 % MC, probably due to the higher viscosity and binding ability of the gum. Utilization of 2.5 % MC produced lower coating loss and frying loss and also a higher cooking yield. They also determined an adverse correlation between cooking yield and frying loss during the increase in frying time. The results of this study were similar to the findings in the literature.

Moisture, fat and penetrometer values

In the ANOVA of moisture values of fried nuggets, significant effects of predusting materials ($p<0.05$) and frying times ($p<0.01$) were noted, whereas batter materials were not found to be significantly effective ($p>0.05$). The values for fat were not significant for the effects of predusting materials and batter materials ($p>0.05$); the frying times, however, were significant ($p<0.01$). The ANOVA results for the penetrometer values showed significant effects of the predusting materials ($p<0.01$) and frying times ($p<0.01$), although the effects of the batter materials were not significant ($p>0.05$).

The moisture and fat rates of fresh meats were 74.34 and 2.1 %, respectively, although the moisture rates decreased and the fat levels increased in the samples after frying. Regarding moisture, the mean values of the samples predusted with SPI had the highest score at 54.31 %. Similarly, they showed the highest penetrometer value at 1.87 cm (Table 4).

Considering the frying time, the highest moisture and the lowest fat were determined at 2 min. The moisture loss and fat absorption increased as the frying time increased (Fig. 2). The penetrometer values, however, decreased as the frying time increased, with the highest value determined at 2 min (Fig. 3).

Among all the samples, those coated with SPI revealed the highest moisture and penetrometer values, probably due to the highest adhesion effects of SPI, because of its smaller particle size and higher protein rate compared to zein and bread crumbs. Its stronger coating structure prevented moisture migration from the nuggets, thus ensuring softer meat texture and higher penetrometer values. The lower moisture rate and the higher fat rate could be due to the destruction of the

Table 4. The effect of coating materials on the mean values of moisture, fat and penetrometer values in coated nuggets after frying

Coating material	*N*	*w*(moisture)/%	*w*(fat)/%	Penetrometer values/cm
Predusting				
control	6	$(46.03\pm7.42)^{b}$	$(8.99\pm1.03)^{a}$	$(1.38\pm0.16)^{b}$
zein	18	$(47.72\pm1.39)^{ab}$	$(10.97\pm0.47)^{a}$	$(1.13\pm0.09)^{b}$
SPI	18	$(54.31\pm0.88)^{a}$	$(11.39\pm0.50)^{a}$	$(1.87\pm0.08)^{a}$
Batter				
control	6	$(46.03\pm7.42)^{a}$	$(8.99\pm1.03)^{a}$	$(1.38\pm0.16)^{a}$
0.1 % CMC	12	$(52.01\pm1.52)^{a}$	$(11.01\pm0.60)^{a}$	$(1.44\pm0.14)^{a}$
0.2 % CMC	12	$(50.47\pm1.82)^{a}$	$(11.07\pm0.72)^{a}$	$(1.47\pm0.13)^{a}$
0.3 % CMC	12	$(50.57\pm1.86)^{a}$	$(11.47\pm0.44)^{a}$	$(1.58\pm0.19)^{a}$

N=total number of samples; different letters in superscripts represent statistical differences among samples

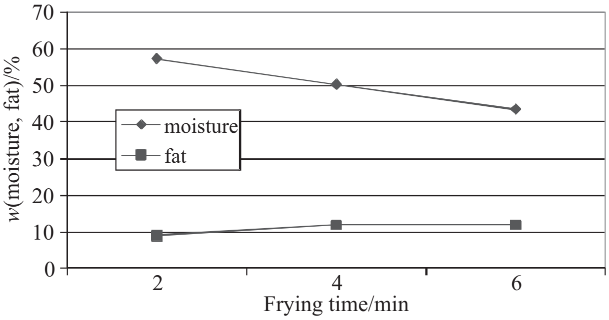

Fig. 2. The effect of frying time on the mean values of moisture and fat in coated nuggets after frying

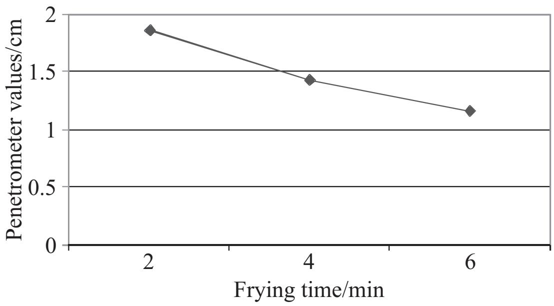

Fig. 3. The effect of frying time on the mean values of penetrometer in coated nuggets after frying

coating materials and meat structure during increased frying time. The breakdown in meat protein structure, particularly during long frying time, increased moisture loss and fat absorption. A hard crust and tough meat texture were formed when the frying time increased. The penetrometer values decreased.

Similar to our findings, Dogan *et al.* (*26*) determined that moisture loss and fat absorption in chicken nuggets coated with soy flour and rice flour increased with frying time. They stated that soy flour caused the highest moisture rate at the end of frying due to its hard crust as a barrier to mass transfer. Sahin *et al.* (*10*) indicated that chicken nuggets coated with different gums had higher moisture rate than control after frying, hardness and oil rate of samples increased whereas the moisture rate decreased during frying. Kılınççeker and Küçüköner (*5*) observed a decrease of moisture loss in chicken drumsticks coated with different protein-based materials during deep frying. Gennadios *et al.* (*8*) reported 16.4 % decrease in moisture loss in coated chicken meat during frying. Similarly, Mallikarjunan *et al.* (*27*) observed 14.9, 21.9 and 31.1 % decrease in moisture loss in fried potatoes coated with various coating materials. Akdeniz *et al.* (*21*) reported a drop in the moisture rate and fracturability values in coated carrot slices when fat rate and frying time were increased.

Sensorial properties

Regarding the ANOVA for appearance, the effects of predusting and batter materials were not significant, whereas those of frying time certainly were significant ($p<0.05$). For colour values, all factors were not significant ($p>0.05$). Considering the odour values, only predusting ($p<0.01$) and batter ($p<0.05$) materials were significant. Finally, only predusting materials were found to significantly affect the taste and flavour ($p<0.01$), structure and texture ($p<0.01$) values; the other factors did not.

Regarding predusting, control and SPI had the highest effect on odour, at 6.92 and 6.21, respectively. The highest values for taste and flavour were in the control sample and in the samples coated with SPI at 6.78 and 6.29, respectively; while for structure and texture they were in the control sample and in the samples coated with SPI at 6.58 and 6.44, respectively. The highest mean value for odour among battered samples was seen in the control samples at 6.92. However, the effect of gum levels on odour was not found to be different (Table 5).

As shown in Fig. 4, the appearance values increased with increasing frying times until 4 min, and then began to decline.

The highest score for odour and taste had the control and SPI-treated samples. Zein had an unpleasant odour and taste. The highest mean values of the structure and texture were affected by the characteristics of the control samples and SPI coating. In particular, the coating with SPI increased moisture rates in the nuggets after frying, and improved the chewing quality of the meat. The decrease of odour mean values in battered samples compared to the control was related to the fried

Table 5. The effect of coating materials on the mean values of sensory analysis in coated nuggets after frying

Coating material	*N*	Appearance	Colour	Odour	Taste and flavour	Structure and texture
Predusting						
control	6	$(6.15\pm0.24)^a$	$(6.25\pm0.30)^a$	$(6.92\pm0.19)^a$	$(6.78\pm0.22)^a$	$(6.58\pm0.16)^a$
zein	18	$(5.13\pm0.37)^a$	$(5.15\pm0.40)^a$	$(5.24\pm0.21)^c$	$(5.33\pm0.24)^b$	$(5.33\pm0.34)^b$
SPI	18	$(5.58\pm0.20)^a$	$(5.67\pm0.22)^a$	$(6.21\pm0.14)^b$	$(6.29\pm0.20)^a$	$(6.44\pm0.18)^a$
Batter						
control	6	$(6.15\pm0.24)^a$	$(6.25\pm0.30)^a$	$(6.92\pm0.18)^a$	$(6.78\pm0.22)^a$	$(6.58\pm0.16)^a$
0.1 % CMC	12	$(5.18\pm0.34)^a$	$(5.33\pm0.40)^a$	$(5.62\pm0.27)^b$	$(5.47\pm0.30)^a$	$(5.76\pm0.33)^a$
0.2 % CMC	12	$(5.44\pm0.43)^a$	$(5.44\pm0.44)^a$	$(5.65\pm0.27)^b$	$(5.92\pm0.30)^a$	$(5.84\pm0.42)^a$
0.3 % CMC	12	$(5.45\pm0.34)^a$	$(5.46\pm0.38)^a$	$(5.90\pm0.26)^b$	$(6.03\pm0.16)^a$	$(6.05\pm0.37)^a$

N=total number of samples; different letters in superscripts represent statistical differences among samples

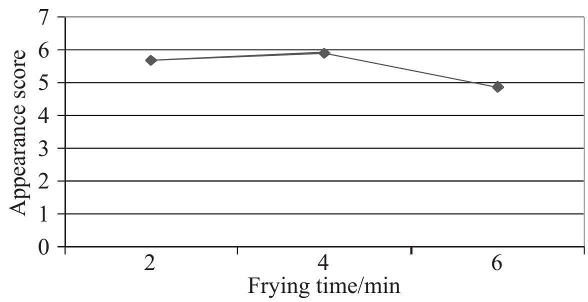

Fig. 4. The effect of frying time on the mean values of appearance of coated nuggets after frying

odour suppressed by the gum solutions. In addition, CMC batters themselves are not odouriferous. They probably decreased the odour by forming films on the nugget surfaces.

The highest mean value for appearance was obtained for samples fried for 4 min, which resulted in desirable colour and surface properties. At this time, the best golden-red colour with no surface cracks on the product was obtained than at any other frying times.

The results of the sensory analysis were similar to the results in the literature related to coating materials based on protein and polysaccharides, such as gums or their mixtures. All sensory properties of the coated nuggets were at acceptable levels (*2,7–9*).

Conclusions

Predusting and batter materials increased performance values compared to the control samples. SPI showed the best results in the coated nuggets. No statistical difference was observed among different levels of CMC used as the batter material. SPI increased the penetrometer values, and decreased moisture loss and fat intake in chicken nuggets. However, no significant effects of the batter materials on these values were observed. SPI showed better effect on sensory properties, but CMC reduced the odour values. Frying loss, moisture loss and fat absorption in the nuggets increased when the frying time increased, although the yield and penetrometer values decreased. The appearance values decreased at 2 and 6 min, but they increased at 4 min of frying time. Therefore, using SPI as predusting material, 0.1 % CMC as batter, and 2 or 4 min as frying time in the chicken nugget coating process gave better results than any other process combinations.

Acknowledgements

The author would like to thank the University of Adiyaman (Project number: AMYOBAP2009-3) and Adiyaman Banvit Co, Turkey, for their financial support for this study.

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