Artificial Neural Network Modeling of Moisture and Oil Content of Pretreated Deep-Fat-Fried Kurdish Cheese Nuggets

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Abstract

In this research, the effects of chitosan (CH) (0, 0.5 and 1.5%) on moisture and oil content of deep-fat-fried Kurdish cheese nuggets was studied, and artificial neural network was applied for modeling of these parameters during frying. Either pretreated or control samples were fried at 150, 170 and 190°C for 0, 1, 2, 3 and 4 min. The results indicated that moisture content decreased with increasing frying time and temperature. The highest reduction in fat absorption during frying was observed in samples were coated with batter containing CH (1.5%) that include 19.42%. An artificial netural network was developed to estimate moisture and oil content of fried cheese nuggets. The developed artificial neural network which included 19 hidden neurons could predict moisture and oil content with correlation coefficient of 0.92 and 0.92 for moisture core and crust and 0.84 and 0.85 for oil content, respectively. These results indication method for moisture and oil content of deep-fat-fried Kurdish cheese nuggets.

Keywords: Artificial neural network, deep fat frying, Kurdish cheese nugget, chitosan

I. INTRODUCTION

The popularity of the frying process can be attributed to certain features of fried foods. Fried foods have good odor and visual appeal due to the golden brown color [1, 2, 3]. However, one problem in connection with batter-fried foods is the significant amount of oil absorption during frying [4]. Oil uptake by the product is an important issue as it affects its nutritional and organoleptic qualities [5].Since the demand for high quality and healthy food is increasing globally, one of the main research fields in food science and technology is the development of methods to produce fried products with less oil uptake during frying [6]. Intelligent models such as artificial neural network (ANN) can be employed to overcome this limitation. The power of ANN lies in its ability to represent both linear and nonlinear relationships between inputs and outputs and in its capability to learn these relationships directly from the modeled data without any knowledge about the physics of the phenomenon. ANN is composed of interconnected nonlinear simple processing elements called neurons or nodes, which are inspired by the way biological nervous systems and performs parallel computations for solving specific problems [7, 8] In recent years, some authors have utilized ANN to predict physical attributes of food products. Mohebbi et al. (2009) employed ANN and multiple linear regression (MLR) to forecast moisture content of dried shrimp by analyzing color features. Their results betokened 0.86 and 0.80 coefficient of determination could be achieved by ANN and MLR, respectively. The ability of an ANN depends strongly upon its topology. Determination of optimum number of hidden neurons and learning parameters is usually performed by trial and error method. Therefore, the objectives of this research were (1) to investigate the effect of frying time and chitosan at different concentrations on moisture and oil content (core and crust) of deep-fat-fried cheese nuggets and (2) to model the kinetics of frying process applying artificial neural network.

2. MATERIALS AND METHODS

2.1. Sample preparation

Wheat flour, Kurdish cheese, sunflower oil and all other ingredients used for the experiments were supplied from the local market. The characteristics of wheat flour and Kurdish cheese are presented in Table 1. A control batter was prepared by mixing wheat flour (90.8%), baking powder (3.1%), flavoring (pepper) (0.6%), and salt (5.5%).To determine the effects of chitosan on deep-fat-fried cheese nuggets, chitosan (sigma, low molecular weight) (0, 0.5 and 1.5%) were replaced with the same amount of wheat flour. The water/dry mix proportion was always 1.2:1 (w/w). The temperature of the water before mixing was 20°C. The ingredients were mixed in a mixer (Moulinex, type BM4) for 2 min. The dimensions of the cheese nuggets were 4.5cm (diameter) × 1.5cm (thickness) ± 0.2cm. Cheese samples were immersed individually into the batter suspensions for 30 s and allowed to drip for 30 s and immediately coated with the breading material**.**

2.2. Frying

Frying was performed in thermostatically temperature-controlled fryer (Black and Decker, Type 01) containing 1.5 L refined sunflower oil (Nina, Iran). Sunflower oil was chosen due to its high smoking point. The fresh oil was preheated for 1h prior to normal frying. Four samples were placed in a wire basket and then submerged for 0, 1, 2, 3and 4min at 190˚C. After each frying batch, the oil level was checked and the oil was replaced after 6 h frying time. Then, samples were allowed to drain for 30 s before being blotted gently with dry tissue paper to remove excess oil on the surface.

2.3. Moisture content analysis

The crust and core portions of the cheese nuggets were carefully separated by hand for moisture and oil content analysis [10]. Moisture content determination was performed according to AOAC (1984) procedure. The crust and core of a cheese nugget were separately dried in a conventional oven (Memmert, 154 Beschickung loading, model 100–800, Germany) at 105˚C for 24 h. The samples were cooled in desiccators. Moisture content (db) was determined as following:

$$MC\,(db) = \frac{W - W_{ov}}{W}$$

W and W_{ov}: samples after and before putting in the oven

2.3. Fat extraction

Fat content was determined by the Soxhle method using petroleum ether as outlined in AOAC official method 991.36 [12]. The dried samples were subsequently ground using a blender. The ground sample (2–4 g) was weighed with an electronic balance (TR-4102D, Denver Instrument Co., Denver, CO) and placed in a thimble. Fat was extracted in the solvent extractor using petroleum ether (extra pure) during a period of 6 h. The thimbles were then dried at 105˚C for 60 min to remove residue solvent and moisture and were cooled in a desiccator prior to weighing.

2.4. Neural network modelling

In this study, a multi-layer perceptron (MLP) network based on back propagation learning rule was used to model moisture and oil content (core and crust) cheese nugget during frying. The MLP network is probably the most popular neural network in engineering problems in the case of nonlinear mapping. It consists of an input layer, one or more hidden layers and an output layer. The input nodes receive the data values and pass them to first hidden layer nodes. Each one sums the inputs from all input nodes after multiplying each input value by a weight, attaches a bias to this sum, and passes on the results through a nonlinear transformation function. This forms the input either for the second hidden layer or the output layer that operates identically to the hidden layer. The resulting transformed output from each output node is the network output. The network needs to be trained using a training algorithm such as back propagation. Basically the objective of training patterns is to reduce the global error. The goal of every training algorithm is to reduce this global error by adjusting the weights and biases [13].

The working variables of (coating, frying temperature and time) were used as inputs, whereas Moisture and oil content (core and crust) as the outputs. Hyperbolic tangent activation function was selected to be used in the hidden layer, while linear function was used in the output layer.

$$\tanh(x) = \frac{e^{x} - e^{-x}}{e^{x} + e^{-x}}$$

In this study, experimentally collected data (totally 270 data) were randomly divided into three groups: training (55%), validating (20%), and testing data (25%). The first partition was used to perform the training of the network. The second one was applied to evaluate the quality of the network during the training, and the last partition was utilized for estimating the performance of the trained network on new data, which never was seen by the network during the training. Back-propagation algorithm with the momentum learning rule was used to implement supervised training of the network. Back propagation is based on searching an error surface (error as a function of ANN weights) using gradient descent for point(s) with minimum error. In this algorithm, training starts with randomly initialized connection weights. The response to each neuron in the output layer is then calculated and is compared with the corresponding desired output. Errors associated with the output neurons are propagated from output layer to the input layer through the hidden layer to modify the weights. Different statistical parameters namely mean squared error (MSE), normalized mean-squared error (NMSE), mean absolute error (MAE), and correlation coefficient (R) were calculated based on testing data and applied to study the performance of ANN in prediction of moisture and oil content of fried mushroom. The mathematical equations of these statistical terms were presented by Fathi et al. (2009).

II. RESULTS AND DISCUSSION

2.1. Moisture content

It is noteworthy that moisture and oil content of Kurdish cheese is 54.07 and 34.8% (db), respectively.

ANOVA showed that the batter formulations, frying time and interaction between treatments were significant ($p < 0.05$) on moisture content for both the crust and core parts of the cheese nuggets (table 2). The effect of batter formulation on the moisture content (core and crust) of deep-fat-fried cheese nuggets is given in figure.1. As the results show, cheese nugget coating with batter contain chitosan (1.5%) provided the highest moisture content for both the core and crust parts at the frying. Reduced moisture loss in samples coating with batter contain chitosan (1.5%) can be attributed to the chitosan has ability of film formation and maintain moisture. Chitosan dissolved in water through the formation of hydrogen bonds leads to formation of gel [15].Consequently, high strong gel reduces damage caused by the evaporation and moisture emissions to surface nugget [15]. This is in agreement with wu et al. (2000) batter contain chitosan (2%) effective in retarding moisture loss and lipid oxidation for precooked beef patties. In addition, chitosan increase consistency coefficient of batter results increase thickness of crust and limited moisture transfer to the crust.

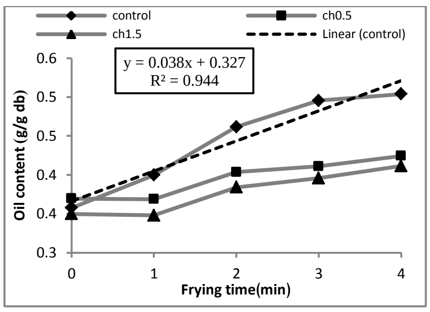
The crust and core moisture contents were decreased by rising the frying time with an initial rapid decrease in the first minute of frying due to the rapid moisture loss from the crust portion and loss of the surface water in all samples. Other researchers have reported similar results with different fried [17].The second drying stage was due to the onset of moisture loss from the core portion of the cheese nuggets. The emission of moisture from crust layer is more rapid than the transfer of the moisture from the core to breading layer. Ngadi et al. (2007) reported similar trends for the coating and core parts of chicken nuggets fried in the same conditions.

2.2. Fat content

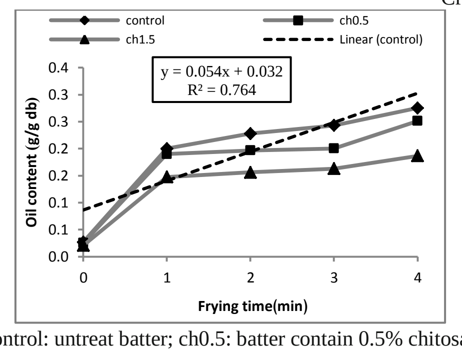
The batter formulation and frying time had high significant influence ($p < 0.01$) on the oil content of crust and core of the cheese nuggets. As it is shown in Table.3, control samples had the highest oil content in core and crust for all of frying times. Samples coated with batter containing 1.5% chitosan had the lowest oil content in core and crust among all formulations because oil content would be lower in less moisture loss. Moisture content of deep-fat-fried foods is an important factor in determining oil uptake. During frying, moisture loss creates cavities or pores as well as passage ways in the food. During frying, the oil penetrates through these cavities which are known as capillary pores [17].Previously, a linear relationship between oil uptake and water removal was reported [18].The improved water vapor barrier properties of chitosan added batter caused a reduction in oil absorption in to the product.

As it is shown in Figure.1 the oil uptake in the crust was higher than the core of cheese nugget. For example the mean values of the oil content of the crust and core portion of cheese nuggets increased from 0.027 and 0.358 g/g (db) to 0.275 and 0.504 g/g (db) for control samples, respectively at 190 °C for 4 min. Several studies have shown that oil uptake during deep-fat-frying is localized in the crust. Oil tends to concentrate near edges, corners and broken “slots” [17]. Frying time is an important factor in influencing oil uptake. In this research, oil absorption (core and crust) was increase during frying time for all batter formulations (Figure. 1). Ansarifar and et al (2012) reported that oil uptake is initially high, and then remains stable to become linear with time during deep-fat-frying of potatoes. The initial high rate of oil uptake was attributed to the large difference in oil concentration between the surrounding oil and the initial oil concentration in the food.

Core



Crust



Control: untreat batter; ch0.5: batter contain 0.5% chitosan; ch1.5: batter contain 1.5% chitosan

Fig 1. Oil content g/g (db) in the crust and core of cheese nuggets fried at 190°C for 0,1,2,3 and 4 min.

2.3. Artificial Neural Network Modeling

The results showed that ANN with 19 neurons in hidden layer gave the lowest prediction error with MSE and NMSE of 0.229, 0.912 and 0.133, 0.492 for prediction of moisture core and crust, respectively and 0.307, 0.882 and 0.740, 0.318 for oil content core and crust of fried cheese nuggets, respectively. The matrices of weights (W1 matrix of 19×3 between input and hidden layer and W2 matrix of 19×2 between hidden layer and output layer) and bias values (B1matrix of 19×1 for hidden layer and B2 matrix of 2×1 for output layer) of optimized network, which could be applied in a computer program for online estimation of moisture and oil content of fried cheese nuggets are the following: values in rows of matrix of W_2 representing the weights of the connections between hidden neurons and moisture and oil content neurons in output layer, respectively. The experimental values of moisture and oil content artificial neural network (ANN) predictions for each test data set were plotted for estimation the performance of developed intelligent model against the new data (Fig. 2). The results revealed that an acceptable agreement (correlation coefficient of 0.92 and 0.92 for moisture core and crust and 0.84 and 0.85 for oil content, respectively) between the predicted and experimental data can be achieved using ANN model.

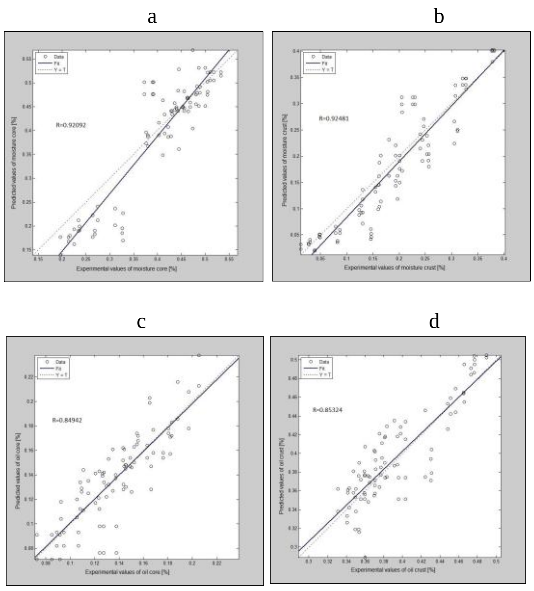


Fig. 1. Experimental versus predicted values of moisture content (core and crust) (a,b) and oil content (core and crust) (c,d) of fried cheese nuggets using ANN model

III. CONCLUSION

The influences of operational parameters and different pretreatments on moisture and oil content (core and crust) of fried cheese nugget were investigated. It was indicated as the frying times increased, the moisture content diminished while oil uptake increased. The results showed that oil and moisture content of cheese nuggets during frying were found to be correlated. The greatest reduction in fat absorption was observed when samples were coated with batter containing 1.5% chitosan. Artificial neural network model was developed for estimation of moisture and oil content of fried cheese nuggets. It was found that artificial neural network with 19 hidden neuron could predict moisture and oil content with high correlation coefficient (0.92 and 0.92 for moisture core and crust and 0.84 and 0.85 for oil content, respectively). Hence, application of ANN can significantly improve the moisture and oil content predictions during frying process of cheese nuggets.

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Table 1. Chemical composition of Kurdish cheese and wheat flour used in the study.

(%)	Kurdish cheese	Wheat flour
Ash	7.83±1.23	065±1.85
Dry matter	46.93±3.45	83.21±4.25
Protein	36.23±2.12	8.54±1.94
Fat	34.81±1.09	1.32±0.36

Table 2. Mean±Std of moisture content g/g (db) Kurdish cheese

Coating	Time (min)	Temperature 190 ºC		Temperature 170 ºC		Temperature 150 ºC	
		crust	core	crust	core	Crust	core
Control	0	0/305±0/009	0/955±0/067	0/305±0/009	0/953±0/065	0/305±0/009	0/955±0/067
	1	0/136±00/4	0/280±0/040	0/110±0/001	0/247±0/061	0/102±0/016	0/233±0/022
	2	0/111±0/024	0/250±0/050	0/110±0/022	0/294±0/033	0/087±0/009	0/224±0/014
	3	0/100±0/013	0/252±0/0247	0/102±0/013	0/243±0/009	0/071±0/013	0/206±0/459
	4	0/096±0/021	0/219±0/0457	0/088±0/006	0/207±0/099	0/078±0/017	0/183±0/031
ch0.5	0	0/352±0/006	1/060±0/337	0/348±0/022	1/060±0/337	0/342±0/028	1/060±0/337
	1	0/252±0/011	0/895±0/309	0/211±018/0	0/849±0/323	0/207±0/020	0/820±0/016
	2	0/226±0/007	0/843±0/391	0/183±0/018	0/782±0/144	0/161±0/023	0/712±0/110
	3	0/186±0/056	0/847±0/277	0/148±0/024	0/664±0/183	0/147±0/007	0/625±0/176
	4	0/182±0/009	0/627±0/158	0/149±0/023	0/606±0/036	0/124±0/006	0/617±0/055
ch1.5	0	0/391±0/016	1/057±0/052	0/401±0/011	1/057±0/052	0/401±0/011	1/057±0/052
	1	0/325±0/014	0/974±0/050	0/245±0/030	0/942±0/033	0/250±0/022	0/921±0/065
	2	0/264±0/009	0/943±0/053	0/228±0/019	0/871±0/004	0/211±0/028	0/799±0/012
	3	0/228±0/079	0/831±0/067	0/184±0/015	0/862±0/101	213±0/014	0/768±0/036
	4	0/198±0/049	0/815±0/004	0/187±0/019	0/762±0/098	0/154±0/011	0/706±0/048

Control: untreat batter; ch0.5: batter contain 0.5% chitosan; ch1.5: batter contain 1.5% chitosan