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Effect of infrared final cooking on some physico-chemical and engineering properties of partially fried chicken nugget

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ABSTRACT

In this study the effects of IR cooking on physicochemical properties of the chicken nugget were investigated. The samples were cooked using deep fat frying, IR cooking, pre-frying-IR cooking and IR cooking-post frying. After treatments, the moisture and fat contents, weight loss, color, textural and sensorial attributes of samples were determined. The moisture and fat contents of the nuggets decreased when the higher heat fluxes and longer process time were applied. The minimum and the maximum total weight loss were observed during PF-IR (6.95 kW/m^2–3 min) and IR-PF (10.25 kW/m^2–7 min). Lower L*, higher a* and b* values were observed as the heat flux and cooking time increased. The IR cooked nugget using 6.95 kW/m^2 and 10.25 kW/m^2 had the lowest and the highest hardness and chewiness, respectively. Fick's law of diffusion was used to determine the effective moisture diffusivity, which varied between 1.09×10^{-8} to 2.69×10^{-8} m^2/s. The estimated values of E_a from the modified Arrhenius type exponential equation in infrared, infrared-frying and frying-infrared cooking process were 4.27, 3.55 and 5.97 kW/kg, respectively. Sensorial properties revealed that the IR cooked and PF-IR cooked nuggets had the similar acceptance to the deep fat fried sample in addition to having significantly lower fat content.

1. Introduction

In the recent years, customers consumed breaded and battered foods like chicken nuggets widely because of having high nutritional value, good sensorial properties, long shelf-life and low cost (Magdelaine, Spiess, & Valceschini, 2008). Deep-fat frying is one of the main unit operations in the production of this kind of fast foods (Gazmuri & Bouchon, 2009). In this cooking method, the food is in contact with the high-temperature fat or oil, above the boiling point of the water, as the heat transfer medium (Varela, 1988). Deep-fat frying affects the physicochemical and sensorial properties of the food like color, texture, taste, water and fat contents (Dana & Saguy, 2006). Undesirable high oil absorption occurs during frying; therefore, high consumption of these high calories products results in diseases corresponding to the obesity (Ngadi, Wang, Adedeji, & Raghavan, 2009). So, several approaches have been proposed including physicochemical pretreatments as pre-drying and pre-cooking, optimization of processing conditions like time - temperature controlling and modification of the food surface such as breading and battering (Bunger, Moyano, & Rioseco, 2003). Blanching of the potato strips using calcium chloride solution reduced the oil absorption during deep fat frying for example (Rimac-Brnčić, Lelas, Rade, & Šimundić, 2004). It was reported that pre-drying of the blanched potato decreased the oil absorption (Lamberg, Hallstroem, & Olsson, 1990). Oil absorption was reduced during frying by pre-baking the tortilla chips (Moreira, Sun, & Chen, 1997). Hence, one of the used modification methods of deep fat frying process is partial frying and alternative heating process as final cooking treatment (Annapure, Singhal, & Kulkarni, 1999).

Conventional cooking ovens with high-velocity hot air convection mechanism have the limitation in the food preparation such as overheating, oxidation, low yield and high energy cost. Hence, alternative cooking methods like infrared radiation (IR) have been introduced in the food industry. IR is part of the electromagnetic spectrum and has a wavelength range between 0.5 and 100 μm. This radiation can be absorbed by the food compounds (water molecules and ions) which result in temperature rising (Cullen, Tiwari, & Valdramidis, 2011). IR heating is more efficient in producing high heat flux in comparison to convective and conductive heating mechanisms (Sandu, 1986). Application of IR has other advantages such as direct heat penetration, faster and uniform heating and lower degradation of nutritional components (Rastogi, 2012). IR heating was applied in pasteurization, drying, thawing and baking but it does not extensively study as a replacement method for deep frying of the nuggets (Aghajanzadeh, Kashaninejad, & Ziaiifar, 2016; Bagheri, Kashaninejad, Ziaiifar, & Aalami, 2016; Salehi,

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Kashaninejad, Akbari, Sobhani, & Asadi, 2016; Salehi, Kashaninejad, & Jafarianlari, 2016). Lloyd, Farkas, and Keener (2004) applied IR treatment in the production of the French fries. It was observed that the overall acceptance of these products was similar to the cooked products using traditional oil immersion frying method; while, lower fat content was observed during this novel treatment method (Lloyd et al., 2004). The researchers found that application of IR heating method as finish-frying step had no considerable effects on the sensorial aspects of the gluten free donuts; but, the IR cooked sample had lower fat content in comparison to the fully fried donuts (Melito & Farkas, 2013). Application of IR thermal treatment in combination with the Ohmic heating (different distances, heat fluxes and times of IR cooking) enhanced the quality of the cooked meatball (Turp, Icier, & Kor, 2016). Considering the advantages of the IR heating, the aim of this study was to evaluate the effects of this novel cooking method, single and in combination with conventional deep fat frying method, on some chemical characteristics (total weight loss, moisture content and fat content), color, texture and sensorial evaluation of the chicken nuggets during different processing conditions.

2. Material and methods

2.1. Preparation of chicken nugget

All used ingredients were prepared from local markets (Gorgan, Iran). The chicken breast was immediately peeled, deboned, washed and stored at refrigerator temperature (4 °C) until experiments. The chicken breasts were first chopped using a Kenwood mincer (Model AWAT950A01, Japan). The chopped chicken meat (88%) mixed completely with onion (10%), salt (1.5%) and curry powder (0.5%). This mixture was formed into a specific shape (3.5 × 3.5 × 1.5 ± 0.2 cm) and chilled to below −10 °C. Each frozen piece of the nugget was dipped for 15 s in the batter (25 °C) consisted of the dry mixture and water (5:3 W/V). The dry mixture contained wheat flour (94%), salt (1%), baking powder as a leavening agent (2.5%) and black pepper powder (2.5%). In order to drip out the excessive batter, the battered nuggets were vertically maintained for 10 s at room temperature (25 °C). The battered nuggets packed into the polyethylene bags and stored at −10 °C until cooking treatments.

2.2. Cooking treatment

2.2.1. Deep fat frying

Deep fat frying of the nugget, as the control method, was performed in a thermostatically temperature controlled fryer (Sergio, Italy) filled with 2.5 L refined frying oil (Mixture of canola, soybean and palm). In order to reach to a fixed temperature (180 °C), this system was turned on one hour before frying the defrosted sample (25 °C). In order to reduce the alteration of temperature during frying, just one sample was fried for 4 min in each frying batch. The used oil was replaced after each batch. After frying, the sample was immediately removed from the oil and its excess surface oil was removed using tissue paper. Before further analysis, the samples were allowed to cool down up to the room temperature (about 25 °C).

2.2.2. IR treatment

An IR heating oven was developed at the Department of Food Process Engineering of Gorgan University of Agricultural Sciences and Natural Resources (Fig. 1). One piece of chicken nugget was placed in a sample holder (39 × 15.5 cm) which was between two cylindrical far-infrared lamps (1500 W). The distance between the sample and each IR lamps was adjusted to 4.5 cm. Using a variable system, samples were exposed to the heat fluxes 6.95, 8.6 and 10.25 kW/m^2 by setting the lamps output powers to 420, 520 and 620 W, respectively. To achieve a constant heat flux, the lamps were turned on 5 min before starting the cooking treatment. The temperature of each nugget was recorded by inserting a T-type thermocouple in the cold point of the sample connected to a data logger (TC-08, Pichotechnology Co, UK). In this study, three different IR processing conditions were applied to study the effect of IR cooking as following:

1. IR cooking (IR): The nuggets cooked using three heat fluxes 6.95, 8.6, 10.25 kW/m^2 for 5, 7 and 9 min in designed IR oven.
2. Pre-frying - IR cooking (PF-IR): Samples first pre-fried for 30 S at 180 °C (similar to Section 2. 2. 1) and then finally cooked in the IR oven using three heat fluxes 6.95, 8.6, 10.25 kW/m^2 for 3, 5 and 7 min.
3. IR cooking - post frying (IR-PF): At first, samples were cooked in the IR oven in three heat fluxes (6.95, 8.6, 10.25 kW/m^2) for 3, 5 and 7 min. Then, the partially cooked samples post fried for 30 S at 180 °C (similar to Section 2. 2. 1).

After frying, all samples were dried and cooled down as mentioned in deep fat frying section.

2.3. Chemical analysis

2.3.1. Moisture content

Based on AOAC standard method (AOAC, 1986), the processed samples were dried to a constant weight at 105 ± 1 °C for 24 h in a hot-air convection oven (FD53, Binder, Germany) to calculate the moisture content (wet basis).

2.3.2. Fat content

The oil content of the cooled fried nugget was determined using the Soxhlet extraction method by hexane as extraction solvent (AOAC, 1990). Oil content was estimated as a percentage on dry-weight basis of the sample.

2.3.3. Total weight loss

In order to determine the total weight loss, the chicken nugget was weighed with a Sartorius electronic balance (GM-300p, Taiwan) before and after frying treatment. The total weight loss (L_T) was calculated using Eq. (1):

$$L_T = \frac{W_i - W_f}{W_i} \times 100 \tag{1}$$

which, W_i and W_f represent the weight (g) of the chicken nugget before and after thermal processing, respectively (Braeckman, Ronsse, Hidalgo, & Pieters, 2009).

2.4. Physical analysis

2.4.1. Color measurement

Image processing method was used to investigate the effect of cooking method, time and heat fluxes on color of the chicken nuggets. A picture of the sample was taken using the Canon Scan LiDE120 Color Image Scanner (maximum optical resolution is 2400 × 4800 dpi) which was completely shielded by a black cover. Image J software (version 1.42e, USA) was used to convert the RGB signals of the taken picture to L*, a*, b* coordinates.

2.4.2. Texture measurement

Textural properties of the chicken nuggets subjected to different IR cooking conditions were determined using texture profile analysis (TPA) test applying TA - XT plus texture analyzer (Stable Micro Systems, UK). At first, each nugget was cut in shape of a cube (1.5 × 1.5 × 1.5 cm) and compressed by cylindrical plate (diameter of 3.6 cm) and 5 kg power cell to perform the TPA test which consists of two cycles of compression. The samples compressed twice, with a 15 S delay between the descents at a rate of 1 mm/s. Various parameters including hardness, springiness, chewiness (gumminess × springiness)