Determination of Physical Properties of Falafel (Fried Chickpea Balls) under the Effect of Different Cooking Techniques

Mohammed M. Ismail, Sebahattin S. Turgut, Erkan Karacabey, and Erdogan Kucukoner
Department of Food Engineering, Suleyman Demirel University, Isparta, Turkey
Email: mohamed_ani3@yahoo.com, {serhatturgut, erkankaracabey, erdogankucukoner}@sdu.edu.tr

***Abstract*—In this study, effect of different cooking techniques on some physical characteristics of falafel is evaluated. Falafel dough was prepared using a standard recipe and fried using microwave (MW), convection (5, 10 and 15 % of sun flower oil added to standard recipe) and traditionally deep frying techniques in sun flower oil at 180 ℃. Moisture content (db%), oil content (db%), textural properties (firmness; g-force and hardness; g-force), colour (*L**, *a**, *b** and total colour change; *ΔE*) and cooking time (min) were determined and also one another critical quality parameter, namely volume increase (%), was calculated by image analyses for cooked falafel samples. The shortest frying time was found as 1 min for MW technique and it was increased up to 16.40 min with convective treatment. According to results, moisture content of samples ranged between 15.12±1.80-48.36±3.50% and the lowest result was belonged to falafels which initially containing 15% oil and cooked by convection, while the highest was found in deep fried samples. The lowest oil content (12.87±0.25%) was found in the sample that was cooked in a convective way with the addition of 5% oil. Among the different cooking techniques the lowest firmness (23.16±1.00) and hardness (18.72±2.08) were observed in deep fried samples. With regard to colour properties, any significant difference was not observed between MW and deep frying techniques for all parameters (p<0.05), however other samples differed from these two (p>0.05). And lastly, the lowest volume increase was observed in the MW cooked samples with 36.66±2.81% compared to uncooked falafel dough.**

***Index Terms*—falafel, physical properties, deep frying, microwave**

I. Introduction

Falafel is a deep-fried ball or patty that is made from dried ground chickpeas, fava beans, or both and soaked for a period of time in water. Then the beans are grinded and kneaded, and the resulting dough is mixed with onion, garlic, spices, then fried in hot oil after its unique tablet form is given [1]-[3]. Sometimes parsley, paprika and sesame seeds may be added to recipe to enhance the taste of falafel. In soaking, baking soda is often used to make falafel puffier. In Syria, chickpea is used to make falafel, and eaten by wrapped in a flatbread with pickled vegetables and tahini-based sauces. In Jordan, a mixture of chickpeas and fava Beans is much more preferred for preparing falafel [4]. On the other hand, in Egypt, Fava Beans is used and called the falafel as Taʿamiya. They often use their traditional bread for making falafel sandwich [4], [5]. In Iraq, only chickpeas is used for falafel and different form other Arabian countries, a traditional bread and a special Indian spice make the falafel have a unique taste and flavour. Just before frying, a cylinder like shape is given to falafel dough and sometimes it is covered with sesames in order to both decorate and add flavour.

It is said that Egyptians are the first who knew about bean as human food, and it was confirmed that falafel was firstly made over that region. It is also approved that by referring to the origin of the name, the word “falafel” is an Egyptian word inherently derived from the word “pepper”, which explains the chili taste which is one of the characteristic of the Egyptian falafel. While the other name of the falafel, which is Ta’amiya, is also endorsed by a large number of Egyptians who say that it comes from the Egyptian dialect which was derived from the Arabic word “ta’am” meaning “taste”. On the other hand, others believe that falafel was first known by the Syrians in the middle ages, and it has spread out to Jordan, Palestine, Lebanon and Egypt through trade trips between those countries, subsequently moved to all other countries through travellers. According to another believe, falafel is known, the first time, in Palestine, and have evolved over time to acquire its current form, and this view is supported by a number of Palestinians scholars. Despite the disagreement over the origin, this popular, cheap and nutritious meal has gained an international notability as both falafel and ta’amiya. And here it cannot be without mentioning the conflict about the historical origin and the first who cooked it and the creativity in making it. The people of the world have greatly agreed to eating falafel and enjoyed its taste, but they are still different about its origin.

Due to frying, falafel has high oil content [6], [7]. Although frying makes a great contribution on taste and flavour, high oil content may cause serious problem in economic view for manufacturers and more notably some health problems for consumers as other fried products do. Thus, several studies can easily be found in the literature which were held to reduce the oil absorption of falafel

Manuscript received February 11, 2018; revised May 21, 2018.

©2018 International Journal of Food Engineering

doi: 10.18178/ijfe.4.3.191-194

during frying. In these studies the efforts were focused on the formulation of falafel and different high molecular weighted carbohydrates such as starch, pectin, cellulose, carrageenan etc. were added to recipe and their effects on some quality attributes were evaluated [6], [7]. However, any study about the effects of different cooking techniques on the falafel quality has been published.

Hence the objective of the present study was to investigate the effects of different cooking techniques on total frying time, colour, texture, volume increase and oil content of falafels.

II. Material and Methods

A. Preparing the Dough and Frying

A commercial and ready to use falafel powder (Alsabbagh) and sunflower oil (as frying medium) were purchased from a local Arabic market in Isparta, Turkey. The dough prepared by mixing 100 g of falafel powder with 90 ml water, then waited for 20 minutes (to make the dough absorb the water well) and then sodium bicarbonate (0.5 g) was added to dough in order to enhance swelling during frying and mixed properly.

Three different techniques were employed for cooking; 1) deep frying (at 180°C), 2) temperature controlled microwave frying (at 180°C) and 3) convective oven cooking. In the last method, the oil were directly added into the falafel dough in three different concentration (5, 10 and 15%) and cooked in an oven at 230°C. For all methods, the time for cooking was previously determined by sensorial evaluation for proper texture and taste (Table I).

B. Analyses

The moisture content of falafels were determined using a bench top moisture analyser (KERN DBS 60-3, Kern & Sohn GmbH, Balingen-Frommern, Germany) (n=2).

Total lipid content (%db) was determined according to chloroform–methanol extraction method suggested by Bligh and Dyer [8] with some modifications presented by Lee, Trevino [9] (n=3). Briefly, 10 g of sample was mixed and homogenized with 30 ml of extraction solvent (chloroform:methanol, 2:1) for 2 min and the mixture was filtrated using Whatman no.1 filter paper. This step was repeated for 3 times and all the filtrates were combined. The resulting solution was moved to a separation funnel, 20 ml 0.5% NaCl solution was added over and the mixture was left for overnight. Following, volume of chloroform layer was recorded and 5 ml of it transferred to a pre-weighed aluminium plate and completely evaporated on a hot plate by preventing from overheating. After 15 min of cooling the weight of dish was recorded and fat content calculated as follows (1).

$$Total\ lipid\ content\ (\%) = \frac{w_L}{w_S} \times \frac{v_C}{5\ ml} \times 100 \qquad (1)$$

where w_L and w_S are weight of extracted lipid and sample, and v_C is total volume of chloroform that was previously recorded.

Colour parameters (L^*, a^*, b^* and total colour change. ΔE) of falafels were measured using a colorimeter (NH310, 3nh, Shenzhen 3nh Tech. Co., Ltd, Nanshan District, Shenzhen, China) (n=8) and the total colour change (ΔE) was calculated as follows (2).

$$\Delta E = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2} \qquad (2)$$

Firmness (F, g-force), hardness (H, g-force) of falafels were determined (n=4) using a texture analyser (TA.XTPlus; Stable Micro Systems Co. Ltd, Godalming, UK). In order to measure these parameters a Perspex blade (A/LKB) for F and a 50mm Cyl. Aluminium (P/50) for H was used. Probe movement speed was set as 1×10^{-3} m s^{-1} for both F and H, and the strain was adjusted to 20% and 70%, respectively.

Volume (cm^3) of falafels were calculated by image analysis in which picture of samples were taken before and right after cooking with a digital camera (Nikon D5200 /18-55) and analysed by using an image processing software (ImageJ 1.50i, developed by Wayne Rasband, National Institutes of Health, USA)(Fig. 1). The volume increment (%) were calculated by comparing cooked falafels with uncooked ones (n=4).

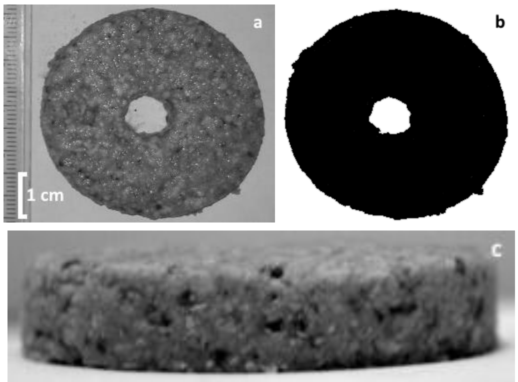


Figure 1. Calculation of falafel volume (a: unprocessed image of falafel (top), b: processed image of falafel (top), c: unprocessed image of falafel (side))

C. Statistical Analysis

All the results were compared by using Minitab Statistical Software (version 16.2.3.0)(Minitab Inc., State College, PA, USA). Tukey pairwise comparison test was performed to determine significance of mean values for comparison at (p<0.05). The results were presented as "mean ± standard error of means".

III. Results and Discussion

The moisture content, oil content and also total time required for proper cooking of falafels were presented in Table I. It is clear that microwave technique was decreased the time for cooking, however, just opposed to that the necessary time for convective cooking was increased up to 16.40 min for the sample containing 10% of initial oil. The shortening impact of microwave frying can be attributed to its effective heat transfer capability and inertial heat generation effect [10]. On the other hand, the different methods used for cooking have shown significant effects both on moisture and oil contents of samples (p<0.05). With respect to moisture content, the highest value was observed in traditional deep-fat frying technique, while the lowest result belonged to the sample C (15%). Beside of that the highest oil content was found in C (15%), and there is no doubt that it is due to its high initial oil content and it was followed by microwaved sample, C (10%), deep fried and C (5%) samples in decreasing order. It is clear that both microwave frying and convective oven cooking led a reduction in final moisture content of falafels compared to that for deep frying. The low moisture content of convectional cooked samples in an oven may be driven from longer cooking time at a higher temperature and also the higher oil content than others. On the other hand, microwave frying was required a shorter time period than that for deep frying. Possibly the reason for having less moisture is the high inertial energy generation that the samples were exposed to. As a result of this heat generation, a pressure gradient, which is very high compared to conventional frying, comes about in food material and induces the altered mass transfer (moisture removal). This pressure increment may also provoke the oil uptake of microwaved samples more than conventional deep fried ones. Although the reverse relationship between moisture and oil content was previously declared, it was also noted that the oil uptake phenomena is closely related with the structure of food material and also the type of oil used [11], [12].

TABLE I. Effect of Different Frying Techniques on Moisture Content, Oil Content and Frying Time of Falafels

Frying method	Moisture content (% db)	Oil content (% db)	Frying time (min)
DF	48.36 ± 3.49^{a}	13.79 ± 0.54^{bc}	1.50
MW	33.99 ± 5.19^{ab}	18.01 ± 2.22^{ab}	1.00
C (5%)	33.70 ± 4.59^{ab}	12.87 ± 0.25^{c}	14.40
C (10%)	24.29 ± 2.93^{b}	17.52 ± 0.45^{ab}	16.40
C (15%)	15.12 ± 1.80^{b}	22.17 ± 0.49^{a}	16.10

- $^{a\text{-}c}$ means in the same column with different superscripts are significantly different (p<0.05).
- DF: deep-fat frying, MW: microwave frying, C: convective cooking (corresponding initial oil content, %)

TABLE II. Effect of Different Frying Techniques on Textural Properties (Hardness and Firmness) and Volume Increase of Falafels

Frying method	Firmness (g-force)	Hardness (g-force)	Volume increase (%)
DF	23.16 ± 1.00^{b}	18.72 ± 2.08^{c}	58.68 ± 16.20^{bc}
MW	53.42 ± 8.25^{a}	29.24 ± 7.04^{bc}	36.66 ± 2.81^{c}
C (5%)	36.65 ± 4.56^{ab}	50.60 ± 4.24^{a}	55.75 ± 5.07^{bc}
C (10%)	27.25 ± 0.78^{b}	39.04 ± 2.88^{ab}	100.46 ± 7.96^{a}
C (15%)	27.58 ± 2.43^{b}	28.14 ± 3.49^{bc}	85.65 ± 4.44^{ab}

- $^{a\text{-}c}$ means in the same column with different superscripts are significantly different (p<0.05).
- DF: deep-fat frying, MW: microwave frying, C: convective cooking (corresponding initial oil content, %)

Textural properties (firmness and hardness, g-force) and volume increase (%) compared to uncooked falafel pies were shown in Table II. The different frying methods were found to be significantly effective on textural properties as well as on the final volume of fried falafels (p<0.05). According to the results, deep fried samples had lowest strength against deformation. The all other cooking methods were resulted in a more rigid structure and the most effective practices in this manner were seem to be C (5%) and microwave procedures.

A similar results were previously observed by Oztop, Sahin [13] and it was noted that low moisture as a result of microwave treatment caused higher harness values. Hence, it was thought that deep fried samples had the lowest firmness and hardness due to their highest moisture and oil contents. For convective oven cooking, long process time, high temperature and having less moisture led to crust formation and dried samples, thus possibly increased the hardness and firmness of samples. A similar argument may be held for microwave frying, as well, but this time the reason for excessive moisture loss was due to inertial heat generation and resulting pressure gradient.

Volume change is also an important parameter during frying of foods because it is strongly linked to mechanical properties and microstructure of cooked material [12]. According to the results, the highest volume increase was observed in convectively cooked samples in an oven while the lowest was found in microwaved one. Similar phenomena could be observed during drying of fruits. At severe drying conditions, such as high temperatures or high air velocity, namely under the conditions that favours rapid moisture removal from material surface, provokes the formation of crust layer keeping volume of food material. However, under more gentle conditions letting the inertial moisture removal (as microwave do), unsatisfying final volumes could be obtained due to collapse of inertial cells [14]. Thus, with a similar approach in our case, the samples, which cooked under the conditions causing rapid surface water removal, tended to have higher magnitude of final volume.

TABLE III. Effect of Different Frying Techniques on Colour Properties of Falafels

Frying method	L^*	a^*	b^*	ΔE
DF	40.33 ± 0.52^{c}	11.48 ± 0.26^{c}	24.56 ± 0.61^{b}	28.89 ± 0.73^{a}
MW	38.89 ± 0.69^{c}	12.74 ± 0.45^{b}	23.13 ± 0.44^{b}	30.93 ± 0.80^{a}
C (5%)	47.71 ± 0.41^{ab}	14.18 ± 0.19^{a}	31.21 ± 0.18^{a}	19.43 ± 0.39^{bc}
C (10%)	49.41 ± 0.51^{a}	13.38 ± 0.22^{ab}	31.48 ± 0.67^{a}	17.84 ± 0.50^{c}
C (15%)	45.97 ± 1.01^{b}	13.22 ± 0.22^{ab}	30.87 ± 0.89^{a}	21.04 ± 1.06^{b}

- $^{a\text{-}c}$ means in the same column with different superscripts are significantly different (p<0.05).
- DF: deep-fat frying, MW: microwave frying, C: convective cooking (corresponding initial oil content, %)

The effect of different cooking methods on colour properties (L^*, a^*, b^*, ΔE) of falafel samples were presented in Table III. There were significant differences between colour values of falafels that were fried using different procedures or cooked in an oven (p<0.05). The lowest a^* and b^* values were found in deep fried and microwaved samples, meaning microwaved samples had more familiar visual characteristics compared to the samples cooked in the oven although significantly low L^* of deep fried and microwaved samples (p<0.05). This phenomena most probably arisen from insufficient heat transfer rate of convective cooking. During heating process applied in an oven, convective force is the circulation of air around the food transferring heat to the material surface. This kind of heat transfer (via air) is much slower than that of through liquids and this situation decreases the rate of non-enzymatic browning reactions, namely colour change [15].

However, in convective cooking method, the thick and dry crust region were undergo non-enzymatic browning reaction rapidly, thus had enhanced colour values and total colour change due the rapid temperature elevation especially at the beginning of frying [12]. The low lightness value observed in microwaved samples may be interpreted as rapid browning. However, microwave systems are known as insufficient on creating brownish colour [15], even if it is desired in some cases. This darker colour observed in microwave fried samples may be attributed to relatively higher moisture removal from these samples. As well-known that light reflection properties of food materials have crucial influence on colour properties. And not only during drying but also as a result of other physical and mechanical processes, considerable alterations take place on reflection properties [16].

IV. Conclusion

In the present study, effects of different frying techniques on some quality characteristics (time for proper frying, moisture and oil content, texture, colour and volume increase) of falafel pies were evaluated. Frying was carried out using three different techniques. One is traditional deep-fat frying (at 180°C) using sunflower oil. Second is microwave frying practice at constant temperature (at 180°C) and it was found to be effective on decreasing the time required for proper cooking. However, some unsatisfying results were come out from this treatment such as high oil content, harder texture and insufficient volume uptake. On the other hand, it was found as most similar colour forming alternative method among other studied ones compared to deep fried samples. Lastly, convective cooking method was applied at three different initial oil concentration (5, 10, 15%) at 230°C. Although, 5% oil containing sample gave promising result about final oil content, with regard to other specification traditional method has seem to be superior in most of the cases.

References

[1] M. H. Gonzalez, *Way to Eat: A Six-step Path to Lifelong Weight Control*., Illinois: Sourcebooks, Inc., 2002, p. 336.

[2] M. Ismail and E. Kucukoner, “Falafel: a meal with full nutrition,” *Food* and *Nutrition Sciences*, vol. 8, pp. 1022-1027, 2017.

[3] J. Leonar, “New ways with falafel,” *Vegetarian Times*, vol. 2, pp. 30-36, 1996.

[4] G. Malouf and L. Malouf, *Artichoke to Za'atar: Modern Middle Eastern Food*, USA: University of California Press, 2008, p. 352.

[5] Y. Raviv, “Falafel: A national icon,” *Gastronomica: The Journal of Critical Food Studies*, vol. 3, pp. 20-25, 2003.

[6] E. J. Pinthus, P. Weinberg, and I. S. Saguy, “Criterion for oil uptake during deep-fat frying,” *Journal of Food Science*, vol. 58, no. 1, pp. 204-205, 1993.

[7] E. H. Mansour, “Quality of deep-fat fried falafel balss as influenced by various fibers and hydrocolloids,” *Minufiya J. Agric. Res.*, vol. 28, no. 2, pp. 491-502, 2003.

[8] E. G. Bligh and W. J. Dyer, “A rapid method of total lipid extraction and purification,” *Canadian Journal of Biochemistry and Physiology*, vol. 37, no. 8, pp. 911-917, 1959.

[9] C. M. Lee, B. Trevino, and M. Chaiyawat, “A simple and rapid solvent extraction method for determining total lipids in fish tissue,” *Journal of AOAC International*, vol. 79, no. 2, pp. 487-492, 1996.

[10] M. E. C. Oliveira and A. S. Franca, “Microwave heating of foodstuffs,” *Journal of Food Engineering*, vol. 53, no. 4, pp. 347-359, 2002.

[11] M. H. Oztop, S. Sahin, and G. Sumnu, “Optimization of microwave frying of potato slices by using Taguchi technique,” *Journal of Food Engineering*, vol. 79, no. 1, pp. 83-91, 2007.

[12] S. Sahin and S. G. Sumnu, “Advances in deep-fat frying of foods,” in *Contemporary Food Engineering*, D. W. Sun, Ed., Boca Raton: CRC Press, 2009.

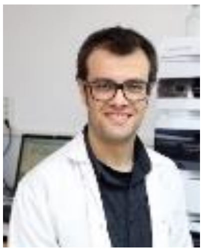
[13] M. H. Oztop, S. Sahin, and G. Sumnu, “Optimization of microwave frying of osmotically dehydrated potato slices by using response surface methodology,” *European Food Research and Technology*, vol. 224, no. 6, pp. 707-713, 2007.

[14] B. Cemeroglu, *Meyve ve Sebze Isleme Teknolojisi 2*, Ankara Nobel Press, 2009.

[15] M. Yost, J. M. Abu-Ali, and S. A. Barringer, “Kinetics of potato color and texture development during baking, frying, and microwaving with the addition of liquid smoke,” *Journal of Food Science*, vol. 71, no. 9, pp. E364-E369, 2006.

[16] P. P. Lewicki and E. Duszczyk, “Color change of selected vegetables during convective air drying,” *International Journal of Food Properties*, vol. 1, no. 3, pp. 263-273, 1998.

Mohammed Ismail was born on September 14, 1988 in Baghdad / Iraq. He received his B.S degree in food science from Baghdad University /Baghdad. Now he is M.S degree in Suleyman Demirel University /Isparta, and one semester of his M.S was in Marche Polytechnic University/ Italy by Erasmus program.



Sebahattin S. Turgut was born in Ankara, Turkey on April 03, 1989. He received his B.S. degree in food engineering from Ankara University, Turkey in 2012 and M.S. degree in Food Engineering Department of Suleyman Demirel University, Turkey in 2016. He is now a Ph. D. candidate at the same institution. The research interests are about food biochemistry, unit operations and novel technologies.

Erkan Karacabey was born in Ankara, Turkey on August 24, 1979. He completed Doctorate in Food Engineering Department of Middle East Technical University in 2009. He has been in Canada for one year as a Visitor Scientist in PARC (Pacific Agricultural Research Center of AAFC. He has publications and projects about Unit Operations in Food Engineering. He has been working as an Assistant Professor in Food Engineering Department of Suleyman Demirel University since 2012.

Erdogan Kucukoner was born in Gumushane, Turkey on December 05, 1965. He completed Doctorate in Food Science and Technology Department of Missisipi State University in 1996. He has publications and projects about functional foods, food chemistry/biochemistry, dairy techologies, food additives and unit operations in food engineering. He has been working as an Professor in Food Engineering Department of Suleyman Demirel University since 2007.