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Effect of Different Cooking Methods on Nutritional Quality, Nutrients Retention, and Lipid Oxidation of Quail Meat

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ABSTRACT

The present study aimed to assess the effects of various cooking methods (frying with and without oil, microwave cooking, steaming, and roasting) on the proximate composition, fatty acid profile, and lipid oxidation of quail meat. The retention values of nutrients were also determined in order to identify the optimal cooking method. Cooking resulted in moisture loss, and the highest reduction was observed in the steaming and microwave methods. On the other hand, the most significant increase in the protein content was observed in microwave cooking, steaming, and frying with oil, while the highest level of total lipids was denoted in frying with oil. In terms of the fatty acid profile, C18:1 *n*-9 increased in all the cooking methods, while C18:2 *n*-6 only increased in frying with oil. In addition, C18:3 *n*-3 increased in frying with oil and decreased in microwave cooking and steaming. The fried samples absorbed the major fatty acids of the cooking oil. The total amount of saturated fatty acids increased in steaming and decreased in the other methods. The total amount of monounsaturated fatty acids increased in all the cooking methods, and the amount of polyunsaturated fatty acids (PUFAs) also increased in frying with oil, while it decreased in the other methods. The ratio of n-6/n-3 significantly reduced in frying with oil and roasting, and the residual level of PUFAs was higher in the frying methods and roasting compared to the other methods. Furthermore, the studied cooking methods increased lipid oxidation in the cooked samples compared to raw meat, and the highest level of lipid oxidation was reported in frying with oil. With regard to the retention values, frying without oil and roasting were considered the healthiest cooking methods.

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Introduction

In the past decade, the global consumption of poultry products has increased [1]. Poultry is superior to red meat owing to its low fat, low cholesterol, and high levels of polyunsaturated fatty acids (PUFAs) [1, 2]. Quails are the smallest birds in the *Phasianidae* family [3]. The valuable taste and dietary properties of quail meat are pivotal to the growing interest in this product [4]. Quail has numerous advantages and over the other species of poultry; for instance, the meat has the lowest calorie level and the highest protein content [1]. In addition, quail is one of the leanest types of poultry and an abundant source of protein and various minerals, such as sodium, potassium, iron, and PUFAs [2]. Quail meat is an ideal food for all ages considering its high meat yield, low shrinkage while cooking, and easy cooking and serving [5].

Heating is applied to food in order to enhance its flavor, inactivate pathogenic microorganisms, and increase its shelf life. The effects of various cooking methods on the proximate composition and fatty acid content are associated with various factors [6]. According to da Silva et al. (1993) [7], factors such as the lipid content, cooking temperature, species, size, and surface contact may affect the lipid composition of meat after cooking. Heat treatment could lead to undesirable modifications, such as the reduction of thermolabile compounds, some vitamins, and fatty acids. Therefore, the changes induced by heat treatment should be identified in order to limit the loss of valuable compounds, improve the process, and provide foods with the optimal nutritional values [8].

The preservation of the nutritional value of foods is a major concern in food preparation. Consumers have limited information about the optimal cooking methods to maintain the

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nutritional value of foods. Therefore, it is important to determine the retention values of nutrients in the foodstuffs that are cooked with different methods. Another important criterion that is widely used to evaluate the nutritional value of foods for human consumption is the n-6/n-3 ratio. It has been well established that a high n-6/n-3 ratio leads to an imbalance in the fatty acid intake and promotes several types of pathogenesis, including cardiovascular diseases, cancer, and inflammatory and autoimmune diseases. However, the increased level of n-3 PUFAs and low n-6/n-3 PUFA ratio exert suppressive effects on the mentioned conditions [8]. According to the British Department of Health, the n-6/n-3 ratio should not be above 4:1 [9].

Heating, such as in cooking methods, causes some reactions in food; such example is lipid oxidation, which changes the composition of meat and may deteriorate meat and meat products [10]. The effects of various cooking methods on the nutritional quality of quails have not been extensively investigated. Some studies have been focused on the effects of cooking on proximate composition and fatty acid content in other poultry species [11-14].

The present study aimed to assess the effects of various cooking methods (frying with and without oil, roasting, microwave cooking, and steaming) on the proximate composition, fatty acid profile, and lipid oxidation of quail meat. Moreover, the retention of nutrients and optimal preparation method to maintain the maximum nutritional quality were evaluated.

Materials and Methods

Sample Collection and Preparation

In total, 60 quail carcasses (weight: 180-200 g), which had been reared in a selected local farm under similar conditions in Chaharmahal and Bakhtiari province, Iran, were obtained and transferred to the food and quality control laboratory of Shahrekord University of Chaharmahal and Bakhtiari within 4-6 hours. Afterwards, the samples were randomly divided into six groups of 10. One of the groups was considered as the control (raw samples), and the samples in the other groups were cooked by various cooking methods.

The quails were fried for two minutes in mixed frying oil at the initial temperature of 180°C in a domestic pan (Table 1). Once fried, the samples were drained for approximately two minutes. The process of frying without oil was performed in a stainless steel pan for 5-7 minutes. In the microwave method, the quails were baked at the frequency of 2,450 MHz and power of 900 W for eight minutes in a microwave (Panasonic, Japan). The quail samples were skewed and roasted on a gas flame for about four minutes. In the steaming method, the samples were cooked at the frequency of 50 HZ and power of 600 W for 25 minutes in a steamer (Moulinex, model: MV 1000, China). The internal temperature of the quail samples in various cooking methods was within the range of 72-74°C. The weight of the raw and cooked meat samples was recorded for additional calculation to determine the retention values. Following that, each quail sample was deboned and separately homogenized as a muscle sample for further analysis.

Table 1. Fatty acid profile of mixed frying oil (%)

Fatty acid		Content (%)	
SFA	C16:0 C18:0 C20:0	31.09	26.7 4.01 0.4
MUFA	C16:1 C18:1 trans C18:1 cis C20:1	38.44	0.16 0.07 38.01 0.2
PUFA	C18:2 trans C18:2 cis C18:3	31.47	0.23 28.74 2.5

Proximate Composition Analysis

The mean samples were analyzed in terms of moisture, protein, total lipids, and ash contents using standard methods [15]. The moisture content was determined by drying the samples in an oven at the temperature of 103°C to the constant weight. In addition, the protein content was analyzed using the Kjeldahl method (N×6.25). Total lipids were determined using the Soxhlet apparatus, and the ash content was gravimetrically determined after heating the samples to the temperature of 550°C in a muffle furnace (Atra 1800T, Atra Corporation, Tehran, Iran).

Fatty Acid Analysis

The fatty acids in the extracted lipids were saponified into the free form by saponification using 0.5 N methanolic sodium hydroxide, and esterification was also performed using 14% boron trifluoride (w/v) in methanol [16]. Fatty acid methyl esters (FAMEs) were determined in an Agilent 6890/Series II gas chromatograph (Agilent Technologies Inc., Palo Alto, CA, USA) equipped with an SP™-2560 fused-silica capillary column (50 m×250 µm; film thickness: 0.2 µm; Supelco Inc., Bellefonte, PA, USA) and specialized with an autosampler and a flame ionic detector. The oven temperature was set at 75°C, maintained for two minutes, raised to 180°C by a gradient of 5°C/min, and maintained for 33 minutes. Following that, the temperature increased to 225°C at the rate of 4°C/min, and the injector and detector temperatures were set at 260°C and 280°C, respectively. In addition, the individual FAMEs were identified using authentic standards (Supelco 37 FAME mixture; Sigma-Aldrich Company Ltd., St Louis, MO, USA) [17, 18].

Determination of Retention Values

The retention values of the nutrients in the quail meat samples were determined using the following formula [19]:

Retention Value (%) = ([Nutrient Content per g of Cooked Meat × g of Cooked Meat]/ [Nutrient Content per g of Raw Meat × g of Meat before Cooking]) × 100

Determination of Lipid Oxidation

The levels of thiobarbituric acid reactive substances (TBARS) in the quail meat samples were determined using the spectrophotometric method described by Kwon et al. (2008) [20]. The minced sample (5 g) was homogenized with 15 milliliters of double-distilled water (DDW) using a homogenizer (T25 Silent Crusher, Heidolph, Germany) for 15 seconds at high speed. Afterwards, the meat homogenate (1 ml) was transferred to a test tube, and 50 microliters of butylated hydroxytoluene (7.2% in ethanol) and two milliliters of thiobarbituric acid (TBA)/trichloroacetic acid (TCA) solutions were added (20 mM of TBA and 15% w/v of TCA). The mixture was vortex-mixed and incubated at the temperature of 90°C in a water bath for 30 minutes. After cooling, the samples were vortex-mixed and centrifuged at 3,000 g for 15 minutes. The absorbance (A) of the resulting upper layer was read at 532 nanometers against a blank (1 ml of DDW + 2 ml of TBA/TCA). The TBARS content was calculated using the following formula and expressed as the milligram of malondialdehyde per kilogram of meat:

TBARS = (A × 288)/156

Statistical Analysis

To evaluate the required differences between various groups, data analysis was performed using the one-way analysis of variance (ANOVA) in the GraphPad InStat software (version 3). In addition, the differences between the mean values were compared using Tukey's multiple comparison test at the significance level of P≤0.050.

Results

Weight Change Determination

The results of weight change after using different cooking methods indicated that all the cooking methods caused a significant reduction in the weight of the quail meat samples (P≤0.050). The rate of weight reduction was estimated at 29.7%, 28.8%, 27.6%, 18.3%, and 16.1% with steaming, microwave cooking, frying with oil, frying without oil, and roasting, respectively.

Proximate Composition

Table 2 shows the effects of various cooking methods on the proximate composition of the quail meat. Accordingly, the moisture content significantly decreased with all the cooking methods (P≤0.050), and the most significant reduction was observed with steaming and microwave cooking. On the other hand, the protein content significantly increased with all the cooking methods (P≤0.050) compared to the control group, and the most significant increase was observed with microwave cooking, steaming, and frying with oil. In addition, the total lipids increased in all the groups compared to the control group; however, frying without oil and microwave cooking caused no significant increase in the total lipids. The most significant increase in the total lipids was observed with frying with oil, followed by roasting and steaming. The ash content significantly increased only with steaming (P≤0.050) compared to the control group.

Table 2. Effects of cooking methods on proximate composition of Quail meat.

Groups	Moisture (%)	Protein (%)	Total Lipids (%)	Ash (%)
Not cooked	75.2 ± 1.47^{a}	20.4 ± 0.42^{a}	1.26 ± 0.06^{a}	1.19 ± 0.14^{acd}
Frying with oil	67.6 ± 1.54^{bc}	29.0 ± 1.10^{b}	5.87 ± 0.34^{b}	1.11 ± 0.07^{a}
Frying without oil	69.8 ± 1.51^{c}	26.0 ± 1.19^{c}	1.80 ± 0.10^{ac}	1.37 ± 0.21^{bcd}
Roasting	69.7 ± 1.32^{cd}	24.1 ± 0.87^{d}	4.29 ± 0.35^{d}	1.08 ± 0.15^{a}
Microwave	64.8 ± 2.44^{ef}	29.3 ± 1.90^{b}	1.49 ± 0.12^{a}	1.41 ± 0.18^{de}
Steaming	63.5 ± 2.26^{f}	29.1 ± 1.89^{b}	2.86 ± 0.23^{e}	1.50 ± 0.24^{be}

$^{a–e}$ Means ± SD within the same line with different superscript letters are significantly different ($P \le 0.05$).

Fatty Acid Profile

Table 3 shows the effect of various cooking methods on the fatty acid profile of the quail meat. The main saturated fatty acids (SFAs) were palmitic acid (C16:0), stearic acid (C18:0), and arachidic acid (C20:0). The main monounsaturated fatty acids (MUFAs) were C16:1 *n*-7, C18:1 *n*-9, and C20:1 *n*-9, and the main PUFAs were C18:2 *n*-6 and C18:3 *n*-3. In general, the C16:0 content significantly reduced in all the cooking methods (P≤0.050), with the exception of steaming, and the most significant reduction was observed with frying with and without oil and roasting. On the other hand, the C16:1 content decreased in frying and steaming and increased in roasting and microwave cooking compared to the control group. The C18:0 content significantly increased in steaming (P≤0.050) and significantly decreased with frying with oil and roasting (P≤0.050) compared to the control group. In addition, the C18:1 cis content significantly increased in all the groups compared to the control group (P≤0.050), and the most significant increase was observed with microwave cooking and frying without oil. The C18:2 cis content significantly decreased in all the cooking methods (P≤0.050), with the exception of frying with oil, and the most significant reduction was observed with microwave cooking. The C18:3 content significantly increased in frying with oil (P≤0.050) and significantly decreased with microwave cooking (P≤0.050) compared to the control group.

Regarding the fatty acid content of the uncooked quail samples, MUFAs had the highest percentage, followed by SFAs, while PUFAs had the lowest percentage. In the cooked quail samples, the content of total SFAs significantly decreased with frying with and without oil and roasting (P≤0.050), while it significantly increased with steaming (P≤0.050). Furthermore, the total MUFA content significantly increased in all the groups, whereas the total PUFA content significantly decreased in all the groups (P≤0.050), with the exception of frying with oil.

According to the obtained results, the n-6/n-3 ratio significantly reduced with frying with oil and roasting (P≤0.050), while no significant difference was observed between frying without oil, microwave cooking, and roasting in this regard.

Table 3. Effect of cooking methods on fatty acid profile of Quail meat.

Components (%)	Not cooked	Frying with oil	Frying without oil	Roasting	Microwave	Steaming
C16:0	28.3 ± 0.55^{a}	24.4 ± 0.33^{bc}	24.9 ± 0.49^{cd}	25.6 ± 0.63^{d}	26.7 ± 0.28^{e}	29.4 ± 0.46^{f}
C16:1 *n*-7	5.88 ± 0.38^{a}	3.60 ± 0.54^{bc}	4.09 ± 0.79^{ce}	6.33 ± 0.51^{a}	7.74 ± 0.26^{d}	4.73 ± 0.70^{e}
C18:0	6.73 ± 0.68^{a}	4.89 ± 0.22^{bc}	6.83 ± 0.45^{a}	5.68 ± 0.53^{c}	7.25 ± 0.59^{ad}	7.87 ± 0.21^{d}
C18:1 cis *n*-9	31.6 ± 0.96^{a}	37.0 ± 0.22^{bd}	39.4 ± 0.59^{ce}	37.7 ± 0.65^{dg}	38.5 ± 0.51^{eg}	33.9 ± 0.56^{f}
C18:1 trans	0^{a}	0.10 ± 0.01^{abcd}	0.2 ± 0.010^{bcd}	0^{a}	0.19 ± 0.03^{cd}	0.14 ± 0.13^{d}
C18:2 cis *n*-6	25.8 ± 0.38^{a}	27.3 ± 0.59^{b}	22.5 ± 0.55^{cd}	22.8 ± 0.13^{d}	18.3 ± 0.42^{e}	22.5 ± 0.57^{d}
C18:2 trans	0^{a}	0^{a}	0.12 ± 0.06^{b}	0^{a}	0^{a}	0^{a}
C18:3 *n*-3	1.06 ± 0.17^{ad}	1.91 ± 0.10^{b}	1.22 ± 0.27^{ad}	1.35 ± 0.06^{a}	00.73 ± 0.05^{c}	0.92 ± 0.13^{cd}
C20	0.20 ± 0.03^{ac}	0.28 ± 0.02^{bcd}	0.22 ± 0.03^{ace}	0.19 ± 0.04^{a}	0.29 ± 0.03^{bef}	0.27 ± 0.06^{adf}
C20:1 *n*-9	0.20 ± 0.03^{ab}	0.26 ± 0.05^{b}	0.13 ± 0.04^{a}	0.18 ± 0.02^{ab}	0.17 ± 0.11^{ab}	0.14 ± 0.04^{ab}
$\sum n$-6/$\sum n$-3	24.74±3.44^{ad}	14.29±0.5^{b}	19.29±4.33^{ab}	16.93±0.7^{cb}	25.16±1.96^{d}	25±4.2^{ad}
PUFAs/ SFAs	0.76	0.9	0.74	0.76	0.55	0.62
SFAs	35.3 ± 1.05^{a}	29.6 ± 0.47^{b}	32.1 ± 0.68^{cd}	31.5 ± 0.50^{d}	34.3 ± 0.72^{a}	37.5 ± 0.62^{e}
MUFAs	37.7 ± 1.33^{a}	41.0 ± 0.63^{b}	43.9 ± 0.65^{cd}	44.2 ± 0.45^{d}	46.6 ± 0.77^{e}	38.9 ± 0.86^{a}
PUFAs	26.9 ± 0.47^{a}	29.3 ± 0.65^{b}	23.9 ± 0.76^{cdf}	24.1 ± 0.16^{df}	19.0 ± 0.430^{e}	23.4 ± 0.55^{f}

Abbreviations: SFAs, saturated fatty acids; MUFAs, monounsaturated fatty acids; PUFAs, polyunsaturated fatty acids. $^{a–f}$ Means ± SD within the same line with different superscript letters are significantly different ($P \le 0.05$).

Retention Values

Table 4 shows the effects of various cooking methods on the retention values of the nutrients in the quail meat. The retention values indicated a trend of the higher loss of the moisture content with frying with oil, microwave cooking, and steaming compared to frying without oil and roasting. Therefore, the highest moisture retention was observed with frying without oil and roasting.

According to the findings, the protein retention value in the cooked quail meat was within the range of 99-104%. However, the difference in the retention values was not statistically significant (P≤0.050). In all the cases, the cooking procedures significantly affected the lipid content, thereby changing the retention of the cooked samples. Among the cooking methods, the lowest lipid retention was observed with microwave cooking and frying without oil, with the retention values estimated at 163% and 175%, respectively. On the other hand, frying with oil had the highest lipid retention value (596%) due to the absorption of fats through the frying medium.

Table 4. Effects of cooking methods on mean retention value of Quail meat.

Components (%)	Frying with oil	Frying without oil	Roasting	Microwave	Steaming
Moisture	69.9±4.72^{a}	83.8±4.91^{bc}	84.6±3.44^{c}	66.7±5.62^{a}	65.0±2.97^{a}
Protein	101±6.60^{a}	104±4.16^{a}	99.0±4.36^{a}	101±3.29^{a}	100±7.64^{a}
Lipid	596±154^{a}	175.1±9.4^{bde}	404.7±39.9^{cf}	163.0±12.2^{d}	314±39.2^{ef}
Ash	40.7±2.82^{a}	58.0±8.52^{bcd}	46.8±6.14^{ae}	51.4±5.23^{ce}	54.8±10.6^{de}
SFAs	59.1±3.03^{a}	74.3±1.17^{bcde}	76.2±1.91^{ce}	70.2±0.48^{d}	76.3±4.07^{e}
MUFAs	81.8±4.45^{a}	100±1.79^{bd}	107±3.20^{c}	95.5±2.99^{d}	79.0±3.05^{a}
PUFAs	58.5±2.69^{a}	55.3±3.17^{a}	58.4±1.89^{a}	39.1±1.19^{b}	47.7±3.11^{c}
C16:0	49.7±3.00^{a}	58.0±1.84^{bcde}	61.4±2.55^{ce}	54.9±0.78^{d}	59.8±3.35^{e}
C18:1cis $w-9$	73.8±3.81^{ad}	91.3±3.51^{bc}	90.1±2.93^{c}	79.0±2.08^{d}	68.8±3.00^{a}
C18:2cis $w-9$	54.5±2.65^{a}	52.2±2.75^{a}	54.5±1.82^{a}	37.6±1.11^{b}	45.8±3.04^{c}

$^{a-e}$ Means ± SD within the same line with different superscript letters are significantly different ($P \le 0.05$).

With regard to the ash retention value, frying without oil was reported to have the highest retention value, while frying with oil and roasting had the lowest retention values compared to the other cooking methods. In addition, the SFA retention value significantly decreased with frying with oil (P≤0.050) compared to the other cooking methods. Among various cooking methods, the highest residual MUFA content was observed with roasting, while the lowest level was observed with steaming and frying with oil. The residual PUFA content was also higher with the frying methods and roasting compared to the other methods.

According to the obtained results, the highest C16:0 reduction was observed with frying with oil, while the highest C16:0 residual content was reported with roasting and steaming. Moreover, the highest C18:1 cis residual content was observed with frying without oil and roasting, and the lowest residual value was reported with frying with oil. The C18:2 cis residual value significantly decreased with microwave cooking and steaming, and the frying methods and roasting had the highest C18:2 cis residual values.

Lipid Oxidation

Figure 1 depicts the effects of various cooking methods on the TBARS of the quail meat. Accordingly, the TBARS level was significantly lower in the raw quail meat (P≤0.050) compared to the samples in the other cooking methods. On the other hand, the TBARS level significantly increased with frying with oil (P≤0.050) compared to the other cooking methods.

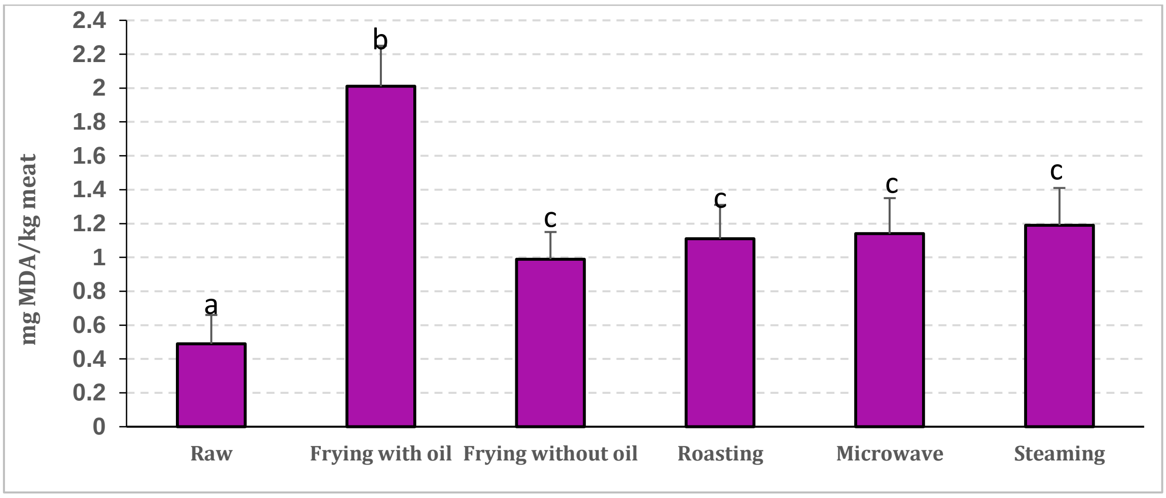

Figure 1. Effect of cooking methods on TBARS levels of quail meat. Values with different superscript letters are significantly different ($P \leq 0.050$).

Discussion

Proximate Composition

According to the results of the present study, the weight of the cooked quails decreased with all the cooking methods due to moisture loss after cooking. Furthermore, it was observed that the cooking methods caused the denaturation of proteins, thereby affecting the ability of the protein to bind to water [21]. This is in line with the findings of the previous surveys conducted on fish, chicken, and lamb chops [22-25]. According to Kumar and Aalbersberg (2006) [24], the water content in the samples cooked by different methods could be attributed to the moisture loss in each cooking method through drippings and evaporation. These authors also stated that microwave cooking causes more drippings than other cooking methods, especially in chicken in comparison with roasting. The findings of the mentioned research are consistent with the results of the present study.

In the present study, protein and lipid contents increased in all the cooking methods due to the fact that moisture loss during cooking leads to the condensation of proteins and lipids [21, 26]. In a study in this regard, Gokoglu et al. (2004) [26] reported that the absorption of fats through frying increased the drying of matter. In the present study, the highest amount of total lipids with frying with oil was due to the absorption of fats through the frying medium. A reverse correlation has been confirmed between fats and water due to the evaporation of water and its replacement by fats [27, 28]. Correspondingly, the lowest moisture and highest lipid content were observed with frying with oil in the current research. This result is in line with the findings of studies performed on sardine [29, 30] and silver carp [31].

In the present study, the steaming procedure had the highest ash content, which might be due to the highest amount of moisture loss. In this regard, Gall et al. (1983) [32] concluded that as lipid absorption increases, the amount of ash loss in the form of inorganic salts would increase as well. This is in line with the results of the present study, which indicated the lowest amount of ash content with frying with oil and the highest lipid content with roasting. A similar study also demonstrated that the ash content was affected by various cooking methods [28].

Fatty Acid Profile

Changes in the fatty acid profile of quails vary in the case of different fatty acids and are dependent on several factors, such as the type of frying oil and duration and temperature of cooking procedures. The major fatty acids in raw and cooked quail meat are palmitic acid (C16:0), oleic acid (C18:1 n-9), and linoleic acid (C18:2 n-6). The fatty acid modifications in poultry during cooking could result from chemical reactions (e.g., oxidation, hydrolysis, and polymerization) or physical changes (e.g., oil absorption from frying oil or drippings from meat). In the present study, palmitic acid (C16:0) and palmitoleic acid (C16: l n-7) decreased with the frying method due to elution by the frying oil, absorbed oleic or linoleic acids [33]. In addition, oleic acid increased in all the cooking methods due to the decreased amounts of higher PUFAs (i.e., oxidative deterioration of PUFAs and lipid hydrolysis). Linoleic acid also decreased in all the cooking methods (except frying with oil) since the autoxidation rate of linoleic acid is rapid. Furthermore, the loss of linoleic acid with the roasting method could be due to the diffusion mechanism [11]. Finally, the increased linoleic acid with frying with oil may have resulted from the absorption of the frying oil that contained 28.74% of linoleic acid.

In the present study, the reduction of SFAs in all the cooking methods (except steaming) could be due to the higher C16:0 content in the raw meat compared to the cooked samples. This is consistent with the previous studies performed on beef [34, 35]. Moreover, Dominguez et al. (2015) [8] reported that the loss of the SFA content through drippings or diffusion is more significant compared to unsaturated fatty acids.

According to the current research, higher MUFA contents were observed in all the cooking methods compared to the raw samples. In addition, lower PUFA contents were observed with all the methods (except frying with oil) compared to the raw samples. The PUFA reduction was due to the effect of temperature on the PUFA content. In this regard, Lee and Dawson (1973) [36] reported that while cooking, PUFAs are more susceptible to oxidation compared to SFAs and MUFAs. Furthermore, they claimed that unsaturated fatty acids are reactive components due to the chemical reactions in heated oil and meat lipids while cooking, which in turn produce free radicals. Alfaia et al. (2010) [37] and Dominguez et al. (2015) [8] have also suggested that the lower content of n-3 fatty acids in cooked samples could be due to the higher susceptibility of PUFAs to oxidative degradation. Bakar et al. (2008) have also reported the loss of PUFAs in fish due to oxidation while cooking [10]. In the present study, frying with oil caused both the MUFAs and PUFAs to increase, while the SFAs decreased, which could be due to the effects of frying oil since C18:1 cis (38.01%) and C18:2 cis (28.74%) are the major fatty acids of mixed frying oils. This is in line with the previous findings in this regard [38, 39]. In addition, the mentioned results are consistent with a study conducted by Agren and Hanninen (1993) [40], which indicated that frying oil mainly affects the fatty acid composition of fried foods. In the present study, microwave cooking decreased the PUFA content (both n-3 and n-6), which is consistent with the studies conducted by Dominguez et al. (2015) [8] on foal meat, Maranesi et al. (2005) [41] on lamb, and Alfaia et al. (2010) on beef [37]. The reduction could be due to the oxidation of PUFAs. This finding is also in line with the study by Yoshida et al. (2005) [42], which demonstrated the decreased PUFA content of various foods, as well as the increased secondary oxidation products originating from fatty acids.

According to Conchilo et al. (2004) [11], chicken, as other types of meat, is not an important source of dietary n-3 fatty acids. Therefore, the n-6/n-3 ratio has been suggested as a useful indicator for the comparison of the relative nutritional values of chicken fat. In the present study, the n-6/n-3 ratio decreased with frying with oil and roasting, while it had no significant changes with microwave cooking and steaming. The reduction could be due to the n-3 increase with frying with oil and n-6 decrease with roasting. This is in congruence with the findings of Bakar et al. (2008) [10], which indicated that the n-6/n-3 ratio in king mackerel had no significant changes with microwave cooking and steaming, while the ratio doubled with frying with oil.

Retention Values

According to the results of the present study, the residual moisture content with frying with oil, microwave cooking, and steaming methods was lowest, which could be due to the lowest moisture content in these methods. Another reason could be the duration of cooking, which was longer in these methods (steaming: 25 min, microwave cooking: 8 min, frying with oil: 5-7 min). The protein retention of the cooked quail meat did not change significantly. It has been observed that the retention values of protein in the fish fillets cooked by various methods were close to 100% [43], which is in line with the results of the present study. Moreover, Lang (1970) [44] stated that the protein content of various meat types did not alter even at the temperature of 100°C.

As mentioned earlier, a reverse association has been confirmed between water and lipid contents; correspondingly, the lowest residual moisture content against the highest residual lipid content was observed with frying with oil in the present study. In addition, frying with oil showed the highest fat retention value (596%)

due to the absorption of fat through the frying medium. In a similar study, Zervou et al. (2012) [39] reported that the increased amount of lipids after frying with oil was due to oil migration from the frying medium to the fish. The mentioned study also demonstrated that the balance of the exchange between the fish-fat and frying oil was positive, indicating that oil absorption by fish was higher than its release. Similar results have been reporeted for silver catfish fillets fried in soybean [25] and sardines fried in sunflower oil [45].

In terms of the ash retention values, frying without oil retained the highest amount of ash in the current research, followed by steaming, microwave cooking, roasting, and frying with oil. In this regard, Kumar and Aalbersberg (2006) [24] concluded that as the moisture retention value decreases, the ash retention value reduces, which might be due to the leaching of ash as inorganic compounds in drippings; this is in line with the results of the present study.

In the current research, the lowest residual SFA content was observed with frying with oil since the retention of C16:0 was lowest. In addition, the lowest residual MUFA content was denoted with frying with oil and steaming due to the lowest residual levels of C18:1 n-9 in these methods. The lowest residual PUFA content was observed with steaming due to the lowest residual C18:2 n-6 content.

Lipid Oxidation

According to the results of the present study, the TBARS value of the quail meat, as the biomarker of lipid oxidation, significantly increased after cooking. This phenomenon was due to the fact that heating could develop oxidative processes in meat [38]. The more significant increase of TBARS in frying with oil compared to the other cooking methods could be attributed to the migration of lipid oxidation products from the frying oil to the quail meat. Notably, the mixed oil used in the current research was an abundant source of unsaturated fatty acids. It has been well established that susceptibility to lipid oxidation enhances with the increased unsaturation of molecules [46].

Conclusion

According to the results, all the cooking methods caused changes in the proximate composition, fatty acid profile, and retention values of the quail meat samples. Based on the retention values, frying without oil and roasting had limited effects on the studied factors and led to the minimum reduction of nutrients compared to the other methods. With regard to proximate composition, frying without oil and microwave cooking caused no changes in the total lipid content of the quail meat; therefore, these methods are suggested as the healthiest cooking methods. On the other hand, the fatty acid composition of the fried samples was rather similar to the used frying oil, indicating that the influence of the oil was more significant on the final composition of the quail meat compared to the lipid composition in the raw state. Therefore, it could be concluded that the use of frying oils with higher PUFA contents may increase the nutritional value of fried meat.

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Conflicts of interest

None declared.

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