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Physical, chemical properties and fatty acids profile of chicken breast and leg meat as affected by marinating and cooking methods

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Abstract:

Fresh leg and deboned breasts chicken were marinated and cooked by boiling, frying, roasting, and microwave. The color values lightness (L*), redness (a*), and yellowness (b*) of fresh and cooked samples were evaluated. Moisture, protein, fat, ash, pH, acidity, cooking loss %, water holding capacity (WHC) % and fatty acids profile were determined.

Marinating treatment decreased the a* and b* values of fresh breast meat and increased a* and b* of fresh leg meat. Whereas, cooking treatments increased lightness and yellowness of all breast and leg meat. The results indicated that marinating treatment and cooking methods were modified the chemical composition of chicken breast and leg meat. Marinated microwave and fried treatments increased the cooking loss to (40.65%). Boiled marinated leg had the highest value of WHC (46.98%). The fatty acids profile was modified by marinating and cooking treatments. Frying treatment increased polyunsaturated fatty acids content of chicken leg and breast meat. The unsaturated/saturated (U/S) ratios for cooked marinated leg and breast meat ranged from 1.44 to3.15.

Introduction:

Chicken meat is one of the leading meat products in the Egyptian markets which represented about 40.99% of the total meat production in Egypt (FAO, 2009). Tenderness and juiciness are considered to be the most important quality attributes of fresh meat and meat products by the consumer (Lawire, 1994 and xiong, 2005). Meat tenderness can be related principally to the connective tissues and myofibrillar protein components of muscle, while the relative contribution to tenderness of these components depends on some factors such as carcass location and processing techniques (chilling, marination,and cooking) (Palka and Daun1999 and Palka, 2003). Marinating is the process of applying an aqueous solution composed of ingredients such as salt, phosphates, acids, sugars, seasonings and flavorings to meat products (Burke and Monahan, 2003 and Sindelar *et al.*, 2003(. It improves the cooking yield, juiciness and tender ness of products as water holding capacity is increased. Marinades

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are incorporated into meat by soaking texture and moisture retention (Young *et al.*, 1992), to enrich the meat flavor (Chen, 1982) to tenderize the fibers of muscle foods and to preserve the product over a longer time (Pauli, 1979).Marinade absorption depends on the poultry part selected. According to Post and Heath, (1983), chicken breasts absorb greater amounts of marinade than thighs. The pH of meat has a great impact on three sensory quality characteristics of muscle foods appearance/color, texture/tenderness, and flavor, all of which affect the consumer acceptance of meat (Offer and Trinick, 1983 and Min and Ahen, 2005). Water holding capacity (WHC) of meat is of great importance in meat industry, as it affects both economic and sensory attributes of meat (Oeckel *et al.*, 1999).

Cooking of meat is defined the heating of meat to a sufficiently high temperature to denature proteins (Davey and Gilbert, 1974). Thermal processing of meat and poultry strongly, influence texture, protein change, cooking yield, and others impotent quality such as juiciness, color, and flavor which are associated with palatably and consumer acceptance of the final product (Wattanachant et al .,2005) . The components of muscle that control toughness are the myofibrillar proteins and the connective tissues proteins. During heating, the different meat proteins denature and they cause structural changes in the meat, such as the destruction of cell membrane, shrinkage of meat fibers (Souzan, 2010), the aggregation and gel formation of myofibrillar as well as sarcoplasmic proteins shrinkage and solublisation of the connective tissue (Palka and Daun,1999 and Tornberg 2005). The analytical measurement of changes occurring during cooking may be carried out by a wide range of methods including cooking loss and color evaluation (Murphy and Marks, 2000). Lipids are an integral part of muscle structure. They are of primary interest to the food technologist because their association with meat product acceptance. The dark meat (thigh) contains higher lipids than white muscle (breast) (Van Heerden *et al.*, 2002).

Lipids in food play a functional role in human nutrition, because of their energy and essential fatty acid contents (Givens and Frayn, 1997). Therefore chemical and biochemical modification of lipids during storage, processing and cooking influence dietetic and sensorial characteristics of meat. Cooking of meat increase the concentration of fat in meat, probably because moisture loss during cooking (Sales, et al 1996). Deep-fat frying process increased the content of most fatty acids presented in chicken breast, pork steak and pork loin (Candela *et al.*, 1996).Among the different meat species chicken supplies fat with one of the highest unsaturated /

saturated U/S ratio (Buege *et al.*, 1998) The fatty acid composition of meat has long been studied but still receives a lot of attention in research because of its implications for human health. Besides a lower total fat intake, human nutritionists were recommended a higher intake of polyunsaturated fatty acids (PUFA), and especially of n-3 or ω-3 fatty acids at the expense of n-6 or ω-6 fatty acids (Rymer and Givens, 2005).

The objective of this study was to evaluate the effect of: 1- marinating 2- cooking methods, (boiling, frying, roasting and microwave) on the chemical composition, physical properties and fatty acids composition of chicken breast and leg meat.

Material and Methods:

Chemicals: All chemicals used were analar grade and obtained from Sigma chemicals (st Louis, Mo, USA).

Muscle samples: Fresh leg and deboned breasts broilers chicken (1.5 ±0.2 kg) live weight and 38 days age obtained from a local processor Minia, Egypt. The leg and breast muscle samples (average weight 150 ± 50 gm) were transferred to Food Science Department Laboratory Minia University after one hour of slaughtering under cooling conditions. Each sample divided into two groups the first group of each is a control (Unmarinated) and the second group of each is marinated. All four group samples were stored at 4°C.

Marinade: The marinade formula consisted of orange juice, water, phosphate, salt, and spices (Table 1). Marinade solution was prepared 1 day before use and stored at 4°c.

Marinating process: The experimental design consisted of four groups, two groups of leg and breast chicken meat used as a control (without marinating). The other two groups were weighed and immersed for 24h in the marinade. The proportion between the meat and the marinade was fixed at 1: 2. The control and marinated samples were then enclosed in sealed plastic pouches and stored in a refrigerator (4ºC) over night before cooking process.

Table 1: Marinade formulation for the leg and breast chicken meat.

Ingredient	Marinade (% meat weight)	Control sample (g)	Marinated sample (g)
Chicken		3000	3000
Water	20		600
Phosphate	0.3		0.900
Salt	4	120	120
Spices*			
Orange Juice	1.2		36

*Spices blend contained 1.71% smoke flavor , 1.71% vinegar, 0.31% ginger , 0.03% thyme , 0.07% clove , 0.88% minced onion , 0.34%

salt , 0.17% red pepper flakes , 0.13% pepper blend , 7.20% cooked diced green peppers.

Samples cooking: The unmediated (control) and marinated samples were cooked by four different cooking methods.

1- Moist heat cooking (Boiling): The samples were placed in cook bags and thermo couples were inserted in their geometric center then vacuum sealed and cooked in a water bath to an internal temperature of 77°c ± 3°c.

2- Frying cooking: The samples were at a time on a temperature regulated hotplate in a Teflon-coated frying pan in sunflower oil at 180°- 200°cfor 6 min. on each side, turning every 2 min. core temperature of the sample at the end of cooking were 76°c ± 2°c.

3- Dry heat cooking: (Roasting): The samples were roasted in a conventional oven at 250°c. The samples were placed individually on mesh rocks in aluminum pans and two thermocouples (Omega Model 199, Engineering Stanford , CN USA) were inserted into the geometric centre of each in order to monitor the internal temperature of 85°c ± 3°c nearly (~20 min.).

4- Microwave cooking: The samples were individually exposed to microwaves and cooked until an internal temperature 78°c was reached (~3min.) full power.

Proximate analysis: Moisture, total protein (Nx6.25), total lipid and ash content of **c**ontrol (unmediated) and cooked marinated leg and breast muscle were determined in triplicate according to the procedures of AOAC, (1995).

PH measurement: Meat sample (10g) was homogenized in 90 ml. distilled water. The pH of slurry was measured using a glass pH electrode (ICM Digital pH, Model 41250, OR, USA).

Color: The color values lightness (L*), redness (a*), and yellowness (b*) of fresh and cooked samples were determined in three replicate using colorimeter (Color Tec PCM, Color meter, NJ, USA).

Cooking loss: Cooking losses were calculated from differences OF the weight of raw and cooked leg and breast muscle.

Water holding capacity (WHC): The samples wrapped in pre-weighed nylon screen and 3 pieces of filter paper (Whatman No.44). The wrapped samples were centrifuged at 3000 Xg for 20 min. The percentage ratio of sample weight difference between, before and after centrifuge, to sample weight before centrifuge provided free water content. The difference between moisture content and free water content was described as the water-holding capacity index (Zheng *et al.*, 1998)

Determination of fatty acids composition. Fatty acids methyl esters of total lipid extracts from unmarinated and cooked marinated leg and breast chicken muscle and sunflower oil were prepared using methanol (1% H_2SO_4 in methanol) for 3 hour at

70°C (Makrides *et al.*,1994). After cooling the resulting Fatty Acid Methyl Esters (FAMS) were extracted with n-hexane, dried with anhydrous sodium sulfate and then concentrated to a small volume with a steam of nitrogen and transferred to micro vials for gas chromatographic (GC) injection. The fatty acid methyl esters were identified and quantified on a Shimadzu GC-14A equipped with flame ionization detector (FID) and C-R4AX chromatopac integrator (Kyoto, Japan). The samples were separated on a 30m SP™ –2380 capillary columns (Supelco, Bellefonte, PA. USA: 0.25 mm diameter, 0.2 μm film thickness) using helium at a flow rate of 0.6ml/min with a spilt ratio of 1:40. The chromatographic run parameters included an oven starting temperature of 100 °C then increased by the rate of 5°C /min to 175°C and were held for 10 min before increasing to 220ºC at 8ºC/ min, with a final hold of 10 min. The injector and detector temperature were both constancy at 250°C. Peaks were identified by comparison of retention times with external standard mixture (Sigma, St. Louis, MO, USA; 99% purity specific for GLC) on the same conditions.

Results and Discussion

Chemical composition: Results in Table 2 demonstrated that the moisture content of breast marinated meat was higher than that of leg marinated meat. The marinating treatment and cooking methods modified the chemical composition of chicken breast and leg meat. The moisture contents of cooked samples ranged from 58.95% (marinated fried breast) to 72.07% (marinated boiled breast). Generally the cooking processes reduced the moisture content of all samples and the highest reduction was found in fried samples. These data are in agreement with those previously reported in the literature (Zheng *et al.*, 1998) who stated that the moisture content was decreased when samples were heated above 60°C. The decrease in the moisture content observed has been described as the fact that leads the other components, such as protein, fat and ash, to increase during the cooking processes, as was previously found by other author's weber *et al.*, (2008) .Total protein contents were affected by the cooking methods that ranged from 16.79% to 31.81%. Total lipid contents of fresh and cooked marinated cooked leg were higher than those of marinated cooked breast. Lipid contents were ranged from 20.73% (marinated frying breast) to 36.3% (marinated microwave leg). Leg muscle (dark meat) had greater concentration of phospholipids compared with breast (white muscle) (Wangen *et al.*, 1971). Cooking tended to reduce the percentage of fat in the dark chicken meat compared to the control, overall our results are in agreement with those reported by Perez, *et al.* (2010). The total ash contents ranged from 3.43 %(

frying breast) to 9.36. % (breast microwave). Ash contents were varied by marinating and cooking processes. The marinating and cooking treatments effect on the chemical composition may be due to mainly water evaporation melting of fats and loss of soluble protein. The proximate composition results from our study were in agreement with those found by (Abeni and Bergoglio 2001 and Al-Najdawi and Abdullah 2002).

PH and Acidity: According to Table (2), the pH values of the samples were increased due to the marinating and cooking methods. The pH value ranged from 5.68 for control breast to 6.20 for marinated microwave cooked leg. Similar increase in pH has been reported by (Sindelar *et al.*, 2003). On the other hand total acidity was ranged from 0.67 %(leg microwave and boiling) to 2.01% (breast frying).It could be noticed that Marinated cooked breast had higher acidity than that of leg. Marinating muscle samples led to an increase in acidity and a decrease in the pH (Burke and Monahan, 2003)

Cooking losses: The results revealed that marinated microwave cooked leg had the highest value of cooking loss (40.65%) followed by marinated fried breast (40.51%) and boiled marinated breast had the lowest value (25.77%) (Table2). Cooking losses of all samples were varied may be attributed to the marinating process and different cooking methods. Marinated breast cooked by boiling, microwave and roasting had lower cooking loss than the unmarinated control boiled (Table 2).These values are comparable to those obtained by Lemos *et al.*, (1999) who reported that marinated chicken samples had lower cooking losses. This due to that marinating increased water binding capacity of meat thus reduced cooking losses and improved meat juiciness (Barbanti, and Pasquini 2005).

Water Holding Capacity (WHC): The treatment effect on thigh is shown in Table 2. The highest WHC was observed in marinated boiled leg (46.98%) followed by marinated roasted breast (42.05%) while the lowest values were found in marinated fried breast and leg. Thus, the water holding capacity of the marinated chicken samples was not dramatically enhanced. The differences in WHC may be due to the cooking methods of samples. Marinating increase water binding capacity of meat (Barbanti, and Pasquini., 2005). The absence of crust, evident on the sample's surface allowing water evaporation and melted fats to escape from the chicken sample is a likely explanation of our cooking loss results. These values are comparable to those obtained by (Murphy and Marks, 2000). The cooking loss was always influenced by the heat treatment time.

Color: Color values (L* lightness, a* redness and b* yellowness) of fresh, marinated and cooked breast and leg meat are shown in Table 3. Marinating treatment decreased a* (redness) and b* (yellowness) of fresh breast meat and increased redness and yellowness of fresh leg meat. Furthermore cooking treatments increased lightness and yellowness of all breast and leg muscles. With heating temperature, meat tended to be lighter and also turned to a brown – grey hue. The lightening is due to an increased reflection of light, arising from light scattering by denatured proteins Young and West, (2001). Fresh muscle and marinated fresh muscle had lower values of lightness than all cooked samples. Color analysis suggested that the marinated cooked sample were generally lighter (higher L*) and more yellow (higher b*) whereas a* (red color) increased as temperature and cooking time increases Resurrection, (2003).It is observed that fried breast and leg muscles had the highest values of redness. Myoglobin is one of the more heat-stable of the sarcoplasmic protein, which is almost completely denatured between 80 and 85°C Lawir, (1994). The compound involved in increasing redness of muscles should be globin hemochrome, in which the iron is in the Fe^{2+} state. Its color is typically dull red. Globin hemichrome, with the iron in the Fe^{3+} state, is largely responsible for the browngrey hue. The balance between hemochromes and hemichromes is affected by the state of meat before cooking and other factors, including species, animal and maturity and muscle type Young el al., (2001).

Fatty acids composition

Tables 4, 5, and 6 illustrate the relative percentage (g /100 g) fatty acids of saturated (SFA), monounsaturated (MUFA), and polyunsaturated (PUFA), respectively for chicken leg, chicken breast and sunflower oil respectively. It is cleared the fatty acid (FA) contents of chicken leg meat were affected by marinating and cooking methods are shown in Table 4. The major FA in control and marinated chicken legs were, Palmitic acid, oleic acid (C18:1), and linoleic acid (18:2). Polyunsaturated fatty acid (PUFA) were identified included linolenic acid (C18:3), arachidonic acid (C20:4) and Eicosapentaenoic (20:5). Saturated fatty acid (SFA) content of chicken leg meat decreased during cooking except frying sample. The microwave cooking increased total monounsaturated (58.19% and 57.55%) and decreased the total saturated fatty acids (25.25% and 24.42%) of control and marinated leg muscle, respectively when compared with the others cooking method. Fried control and marinated leg muscle had the highest value of polyunsaturated fatty acids (20.86% and 25.29%), this may be due to absorption of sunflower oil during frying which has high content of C18:2C and C18:3N3 (Table 6).Our data supported the findings of Miranda *et al.*,(2010) and Ramírez and Cava.,(2005), who reported that the frying processes reduced the proportion of SFA and increased the proportion of MUFA whereas increased the proportion of PUFA in products fried in sunflower oil. While roasted control had the highest value of saturated fatty acids (40.69%).SFA decreased 11% in marinated roasted chicken leg as compared with control sample. However, the USFA increased 11.19% as compared to control sample.

Boiling treatment had an effect on the fatty acids content of control and marinated chicken leg meat compare with other cooking treatments. Cooking of meat increase the concentration of fat in meat, probably because moisture loss during cooking Sales, et al (1996). The lower unsaturated/saturated (U/S) ratios for control roasted and marinated fried were 1.46 and 1.96, respectively. While U/S ratios of all other cooked samples ranged from 2.00 to 3.15. Among the different meat species, chicken supplies fat with one of the highest unsaturated/saturated (U/S) ratios. Buege *et al.*, (1998) stated that the unsaturated/saturated (U/S) ratios of 2.10 for chicken fat.

The FA of chicken breast meat control and marinated are showmen in Table 5 The major FA were represent by C16:0 (21.96-32.15), C18:0 (5.64-7.65), C 18:1N9 (3 8.76- 46.61) and C18:2c (12.42-25.16) .The marinating treatment modified the FA of cooked samples; even though the result on cooked samples did not fully explain the composition differences; this was mainly due to the marinating effect, plus the effect of the cooking loss (water evaporation, melting of fats and loss of soluble proteins) Barbanti and Pasquini, (2005). Marinated boiled chicken breast had the highest value (41.02%) of total SFA but marinated microwave had the lowest value (28.50%) Table 5. Total MUFA varying from 37.85% in the control frying samples to 56.16% in marinated microwave cooking samples. The results presented herein show that marinating and different cooking methods modified of MUFA.The boiling reduced the value of MUFA by 9.6%, the roasting by 5.9%.The increase in MUFA were noticed in the values of marinated frying samples and marinated microwave cooking were 8.33 and 5.59% respectively. The reduction of MUFA, however, must be regarded as an unwanted side effect. From a physiological standpoint, since they do not influence blood cholesterol, as do SFA and they are not precursors of biologically active compounds such as or ω3 FA. These properties of MUFA are presumably the main reason for the health benefits of the Mediterranean diet, in which sunflower oil oleic acid (18:1) is the main lipid source Sirtori *et al.*, (1986). Roasting treatment decreased of SFA and an increase of PUFA fraction. Modifications of fatty acid during cooking could be related to 3 mechanisms: oxidation, loss of fatty acids by diffusion (in roasting) or fatty acid exchange between chicken and oil .The results in this paper concur with those of Scheeder, *et al.* (2001). Control fried had the highest value of total PUFA (28.06%) followed by marinated fried (23.44%). Total USFAranged from 58.98% for marinated boiled to 71.50% for marinated microwave. Deep-fat frying process increased the content of almost all fatty acids present in chicken breast. Finally some of the fatty acids have special behaviors.

Candela *et al*., (1996). During frying, the fat or oil acts as a heat transfer medium and becomes an important ingredient of the fried food because water loss, as well as penetration of oil into the food, takes place. The use of different oils modifies the food characteristics because part of them remains in the fried food, causing a modification of lipid profile and aroma (Ramírez and Cava, (2004). Boiling and roasting process increased the total SFA content of marinated breast meat.

The unsaturated/saturated fatty acid ratios were ranged from 1.44 to 2.51. control and marinated roasted has the same U/S ratios reported by Conchillo *et al*., (2004) who found that roasting did not change the U/S ratio compared with the raw breast samples which ranged from 1.8 to 1.9. Also, chicken, as other

Table (6): Fatty acids content of sunflower oil after frying

Fatty acids %	Fresh oil	Oil after frying
C 12 : 0	nd	0.080
C 14 : 0	0.377	0.383
C 16 : 0	19.425	19.343
C 16 : 1	0.141	0.378
C 16 : 2	0.099	nd
C 18 : 1N9	4.056	4.076
C 18 : 1N7	30.731	30.789
C 18 : 2T	0.098	0.113
C 18 : 2C	39.150	38.762
C 20 : 0	1.182	1.163
C 18 : 3N3	3.362	3.335
C 18 : 4N3	0.313	0.307
C20 : 1N9	0.161	0.158
C 20 : 4N6	0.385	0.476
C 20 : 5	0.145	nd
C 22 : 0	0.082	0.157
C 22 : 5	nd	0.179
C 22 : 6	nd	0.185
C 24 : 0	0.292	0.121
Total saturated	21.358	21.247
Total monounsaturated	35.089	35.401
Total polyunsaturated	43.407	43.358
Total unsaturated	78.496	78.759
Total unsaturated/total saturated	3.675	3.707

types of meat, is not a food can be considered as an important source on n-3 fatty acids in the diet. The modification of fatty acids during cooking could be related to three mechanisms: oxidation, loss fatty acids by diffusion (during roasting), or fatty acids exchanges between chicken and oil (during frying) (Conchillo *et al.*, 2004). No clear change has been observed in fatty acid profile of sunflower oil after frying Table 6.

Conclusion

Marinating and cooking treatments increased lightness and yellowness of all breast and leg muscles. The marinating treatment and the cooking methods were modified the chemical composition and the fatty acid profile of chicken breast and leg meat. Frying treatment increased polyunsaturated fatty acids content of chicken leg and breast meat. Moreover the unsaturated/saturated (U/S) ratios for marinated cooked leg and breast muscle ranged from 1.44 to 3.15.

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الخواص الفيزيقية والكيميائية والاحماض الدهنية للحم صدر وفخذ الدجاج متأثرة بالمارينشن وطرق الطبخ

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تم اجراء عملية المارينشن لعضلات الصدرو الفخذ للحم ا لدجاج ثم اجري عمليات الطهي بالغليان والشى في الفرن والتحمير في الزيت والطبخ في الميكروويف. اجري قياس اللون للعضلات الطازجة وبعد الطهى. ايضا تم تقدير المحتوي من الرطوبة والبروتين والدهون والرماد و(الـ pH) والحموضة والفقد اثناء الطهي والقدرة علي ربط الماء والاحماض الدهنية.

اظهرت النتائج ان المارينيشن ادي الي نقص قيم الاحمرار والاصفرار لعضلات الصدر وزيادتها لعضلات الفخذ الطازج. عمليات الطبخ ادت الي زيادة كل من اللمعان والاصفرار لكل العينات. حدث تغير في التركيب الكيميائي لعضلات الصدر والفخذ نتيجة للمارينشن والطهي. الطهي في الميكروويف أدى لزيادة الفقد بعد الطهي ووصل الي 40.65%. الطهي باالغليان أدى لزيادة قيمة الماء المرتبط لعضلات الفخذ (46.98%) . تغيرت قيم الاحماض الدهنية لعضلات الصدر والفخذ نتيجة للمارينشن والطهي بالتحمير ادي الي زيادة الاحماض الدهنية الغير مشبعة عديدة عدم التشبع. النسبة بين كمية الاحماض الدهنية الغير مشبعة الي كمية الاحماض المشبعة تراوحت من 1.44 الي 3.15