Original Research Article

EFFECT OF DIFFERENT FRYING METHODS ON COOKING YIELD, TENDERNESS AND SENSORY PROPERTIES OF CHICKEN BREAST MEAT

ABSTRACT

This paper focused on the effect of different frying methods on the quality of chicken breast meat. Fresh boned broiler chicken breast meat samples were purchased, frozen, sliced into dimensions. These samples were cooked by air frying (AF) and deep fat frying (DF) methods at 170 ^{0}C, 180 ^{0}C and 190 ^{0}C for 4, 8, 12- and 16-min. Cooking yield and loss were assessed by weight changes before and after frying and tenderness changes were determined by measuring the compression force using instrumental texture profile analysis(TPA). The sensory acceptance and preferences were conducted on the samples by panel of judges. Cooking yield of fried chicken breast meat decreased significantly ($p < 0.05$) with increasing frying temperature and time. Air fried (AF) samples had higher mean cooking yield value of 59.26 % than DF method sample of 50.00 %. Samples fried at lower frying times had significantly ($p < 0.05$) higher cooking yield compared with longer frying time. Cooking loss increased significantly ($p < 0.05$) with increasing frying temperature and time. Samples fried with hot air adopting AF method had lower average cooking loss (40.20%), fat content (6.62 %) and higher compression force (hardness) value (12.39kg/F) than samples fried by DF method which had higher cooking loss (49.47 %) and lower compression force or hardness (12.18 kg/F) and higher fat content (11.88 %). Samples fried for 4 min had significantly ($p < 0.05$) the least value in cooking loss and tenderness, but 8 min fried samples had better sensory attributes than 4 min fried samples, which were pinkish colour in appearance and unappetizing to consumers. Air frying method with the best tenderness value (20.43 ± 1.15 Kg/F), while deep fat frying method-produced samples with its best tenderness value (18.89 ± 0.70 Kg/ F) at 170^{0}Cfor 16 min. Sensory evaluation showed that DF products were moderately crispy (7.19) compared to AF products, which were slightly crispy (5.45). The interaction effect of frying method, frying temperature and frying time was significant for cooking yield, loss and tenderness. However, the overall interaction (frying method x frying temperature x frying time) was found to be significant in coking yield and loss, but not significant in tenderness.

Keywords: Chicken breast, cooking yield, cooking loss, tenderness, frying

1. Introduction

Lawrie and Ledward (2004) have defined meat as flesh of animal suitable for use as food. It is a delicious commodity, derived from skeletal and organ muscles of animal. Muscles are flesh of animal and they include breast that is commonly consumed by elders and youths in rural and urban cities. Breast is a particular muscle of chicken, which Given *et al.* (2011) reported that has mild taste and high levels of protein, mineral, but less in fat, calories and cholesterol than chicken leg muscles.

Meat is a nutrient- rich commodity, which is subjected to heat to improve its texture, make it edible and hygienic. It can be cooked by frying in oil and air frying. Fried foods are widely consumed all over the world due to their attractive colour, distinctive mouth feel, pleasant taste as well as fried flavour and crispy crust formation (Ramirez *et al*., 2004). Frying is a dehydration process that operates by rapid heat and mass transfer in food immersed in preheated hot oil and it results in series of physical and chemical changes in the products (Haizam *et al*., 2008; Andres-Bello *et al*., 2011). Heat results in denaturation of proteins and release of a lot of water and fat. Tenderness is one of the most important eating quality attributes of meat that influences consumers' demand and purchase of meat (Pathare and Roskilly, 2016; Bindon and Jones, 2001; Wang *et al*., 2013).

. Meat has high nutrient composition and it is susceptible to microbial spoilage, tough and undesirable in its raw state. These conditions make it unsuitable for consumption and calls for eating quality improvement through heat application (Tornberg, 2005). Most food frying occurs in oil medium of temperatures between170^{0}C and 190^{0}C to increase sensorial properties development required in fried products (Hubbard and Farkas, 1999).

Frying foods in oils has its own disadvantages even though most frying is usually done with deep fat frying by various kinds of oil that have at least 3 – 10% substantial quantity of linoleic acid to produce attractive and tasty product. Foods are cooked by direct contact with hot oil during frying (Sahin *et al*., 1999) resulting in mass transfer of nutrients between frying oil and the sample, increased internal pressure, thermal decomposition of nutrients and anti-nutritional substances in the frying material, interaction between frying food components and oxidation products of frying oil (Dobarganes *et al*., 2000). Frying process results in exodus of water from the product into the hot oil and oil inlet into the product (Pinthus *et al.*, 1995; Krokida *et al*., 2000). These absorbed oils accumulate more on the surface of fried products and diffuses into the interior of substrate during cooling (Moreira *et al*., 1999b). Besides frying time, meat surface area, moisture content, size and frying oil temperature have serious influence on the amount of oil absorbed (Moreira *et al*, 1997). The oil temperature results collagen solubilisation and increased textural scores of cooked products (Zhang *et al*., 2012; Bordin *et al*., 2013). Deep fat fried products' consumption is associated with excessive oil, which may lead to low consumer acceptance, apart from health problems associated with high oil consumption (Saguy and Dana, 2003); hence the need for low fat containing products that still hold desirable texture and flavour. The need to avoid health complications and advice for consumption of fat-free products forced the health-conscious consumer to opt for alternative methods of frying food products such as air frying. The shift from enticing and palatable deep-fat fried products by consumers to low fat containing products that still hold desirable texture and flavour gave birth to air frying method (Pinthus *et al*.,1999).

Air frying method utilizes hot air technology to cook an item with little or no oil. Air frying produced fried foods as well as French fries prepared from frozen potatoes as reported by Giovanelli *et al.* (2017) but not popular in production of fried meat products. There is paucity of literature on the air frying methods as a means of cooking meat acceptable by consumers for processing meat and its products. Hence, the aim of this study was to ascertain the effect of air frying (AF) and deep-fat frying (DF) methods on quality characteristics of chicken breast meat.

2. Material and methods

2.1. Sample Preparation and Cooking Process of Chicken Breast Meat.

Eight packs of fifty grams of skinless, boned chicken breast (pectoralis major) meat were purchased from a local grocery store at St. Anne – de -Bellevue, Montreal, Canada. These packs were transported to the Food and Bioprocess Laboratory, Department of Bioresource Engineering, Macdonald Campus of McGill University within 30min under cool conditions. In the Laboratory, the packs were frozen at -80^{0}C within 2hours to harden the muscle for easy slicing into 3.0 x 3.0 x 2.0 cm. The cut pieces were divided into two for the two frying methods (air frying and deep-frying). Each portion was further subdivided into three different cooking temperature regimes (170, 180 and 190^{0}C) and each temperature portion further subdivided into five different frying time intervals (0, 4, 8, 12 and 16 min). Each of the samples was weighed and fried in four litres of canola oil, which previously preheated at170 ^{0}C for 2 hours for deep fat frying, and air fryer was preheated at 170 ^{0}Cfor 20 min.

2.2. Cooking Methods of Chicken Breast Meat

The Philips Air fryer - Model HD 9225; was employed in the air frying method, and sample was thereafter, wrapped in aluminum foil, packaged in Ziploc bag and kept in freezer waiting for subsequent analysis. The Delonghi Deep fryer (Type D24527 DZ) was employed in the deep fat frying method. Fifty gram of the sample (W_1) was weighed into sample dish and fried. Thereafter, the products were mopped of oil, after cooking, cooled, reweighed (W_2) and wrapped in aluminum foil, packaged in Ziploc bag and kept in freezer for further analysis. All the cooking experiments were performed in duplicates.

2.3. Determination of Cooking yield and loss of Chicken Breast Meat

The cooking yield and loss of the AF and DF samples were determined following the procedure described by Wattanachant *et al.* (2005).

$$Cooking\ yield\ (\%) = \frac{W2}{W1}\ \text{X}\ \ 100$$

$$Cooking\ Loss\ (\%) = \frac{W1-W2}{W1}\text{X}\ 100$$

WhereW_1 = weight before heat treatment

W_2 = weight after heat treatment

2.4. **Determination of fat content.**

The fat content of the samples was determined by Randall technique (Soxtec method) using standard methods of AOAC (2010). This technique employed six extracting cups and six thimbles in each operation. Three-gram ground meat sample (W_1) was weighed into previously weighed thimbles and the cups weighed (W_2). Thereafter, the thimbles were attached to condenser of extracting units, while 50 mL of petroleum ether was added to each of the cups and mounted on the extracting units. The thimbles were immersed into the solvent and set up locked, water inlet opened and machine switched on, valves connecting the cups and condensers were closed, and immersion timing displayed for 30 min extraction. Thereafter, the thimbles raised up from the solvent and indicator pointer shifted to washing and valves connecting the cups and condenser set closed for 45 min operation. Subsequently, the valves connecting the cups and condensers were opened for the recovery of the solvent and indicator switched immediately to recovery and it lasted for 15 min. In conclusion, the cups were removed and cooled in desiccators (W_3).

$$\text{Fat content (\%)} = \frac{W3 - W2}{W1} \times 100$$

Where w_1 = weight of sample

w_2 = weight of cup

w_3 = weight of cup with fat

2.5. Texture analysis

The hardness test of samples was done with Texture profile analysis (TPA) using a TA-XT2 Texture analyser (Stable Micro Systems) connected to a personal computer (PC) for data logging and analysis via Texture Expert software. The procedures of Bourne (1978, 2002) were utilized in the study. The chicken breast muscle samples were cut into the desired dimensions, and placed on the platform of the analyser and subjected to double compression cycle with 50 mm diameter cylindrical aluminum probe. Thereafter, fitted into 25 kg load cell to 75 % deformation of their original height. The pre-set speed was 1 mm/s, test speed was 5 mm/s, travel distance was 10 mm and rest period was 5 mm/s and exposure time was 5 sec. Four measurements were conducted on each sample to obtain mean and standard deviation. Results were expressed as compression force (kg/F).

2.6. Sensory Evaluation

The chicken breast meat samples were cooked with air frying (AF) and deep fat frying (DF) cooking methods and evaluated sensorial for consumer acceptance and preference by a panel of twenty (20) untrained panelists selected randomly from the Department of Food Science and Technology, Enugu State University of Science and Technology, Agbani.

During the sensorial test, the air fried and deep fat fried cooked samples at 170, 180 and 190 ^{0}C for 8, 12 and 16 min were served in coded forms to the panelists. These samples were served at ambient temperature conditions in white ceramic plates of the same size and panelists randomly picked from the lot and cold water employed for oral rinsing to distinguish between test samples. The samples were assessed for texture using a nine (9) Hedonic scale, where 1 = dislike extremely, through 5 = neither like nor dislike to 9 = like extremely (Ihekoronye and Ngoddy, 1985; Iwe, 2002).

2.7. Statistical analysis

The experimental layout of the study was on 2 x 3 x 4 factorial in completely randomized design (Obi, 2013). All experiments were performed in duplicate. The results were also expressed as mean ± standard deviations and analysed using the General linear model procedures of IBM Statistical Package of Social Sciences (SPSS) version 23.0 and mean comparison was performed ($p < 0.05$) using Duncan New Multiple Range Test (DNMRT).

3. Results and discussions

3.1. Cooking yield of chicken breast meat

The cooking yields (%) of chicken breast muscle cooked by either deep fat frying (DF) or air frying (AF) at temperatures of 170 ^{0}C, 180 ^{0}C and 190 ^{0}C for 4, 8, 12 and 16 min are shown in Table 1. The results showed an overall mean yield of 54.63 %. The module yield was because of loss of moisture and other volatiles during frying. Air cooking (AF) and deep fat frying (DF) are drying heat-cooking methods, which caused higher loss of moisture and other volatiles resulting to shrinkage of the products. Loss of fat from muscle due to meat fat solubility in frying oil or drip in the air-fried products would also contribute to reduction in yield. These losses resulted to an overall cooking loss of 45.37 %.

The results in Table 1 showed that air frying resulted in significantly ($p < 0.05$) higher yield (59.26 %) compared to deep fat frying with a mean yield of 50.00 %. This shows that deep fat frying resulted to higher shrinkage. The lower yield of deep fat fried products could be due to more fat-soluble components of chicken breast muscle leaching into the frying oil in addition to moisture loss.

The results in Table 1 also show that mean yields at temperatures of 170 ^{0}C, 180 ^{0}C and 190 ^{0}C were 57.67 %, 54.19 % and 52.04 %, respectively, and the mean differences were found to be significant ($p < 0.05$). The differences could be attributed to effects of temperature. It was observed, that higher temperatures led to greater losses (shrinkage) presumably due to losses in moisture and other volatiles in addition to lipid losses either as a drip or as solubility in oil. Yancey *et al*. (2011), Garcia-Segovia *et al*. (2007), Combes *et al*. (2003), Obuz *et al*. (2003) who studied cooked meat concluded that lower cooking temperatures yielded a tender product with lower losses. Hearne *et al*. (1978) stated that cooking yield reduction with cooking temperature and time was due to cook drip and evaporative loss. Yield interaction of frying methods and temperatures was found to be significant ($p < 0.050$), suggesting, that the effects on yield caused by frying methods were different at different frying temperatures. The mean yield of AF at 170 ^{0}C was 63.85 %. While that of DF was 51.48 % giving a difference between AF and DF of 12.37 %, the mean yields of the two frying methods at 180 ^{0}C were respectively 58.48 % and 49.89 % with a difference of 8.59 %; whereas the mean yields at 190 ^{0}C were 55.44 % (AF) and 48.64 % (DF), giving a difference of 6.80 %. Thus, the higher frying temperature, the less the difference in yield between deep fat frying and air frying. In other words, higher frying temperatures appeared to equalize the differences in yield between the two frying methods (AF and DF). This change was due to higher temperatures, which caused greater protein denaturation leading to greater loss of water holding capacity with consequent loss of moisture and shrinkage. There is either greater fat drip by (AF) or solubilisation of chicken fat in frying oil (DF) would be more at higher temperatures. All these would lead to greater reduction of yield at higher temperatures.

The results in Table 1 also showed that the mean yields at frying times of 0, 4, 8, 12 and 16 min on average were 65.23%, 57.56 %, 50.16 5, and 45.57 %, respectively. These values showed that the mean frying yields decreased significantly ($p < 0.05$) with increase in frying times. This could be due to the fact that the more frying times, the greater the losses (shrinkage). Of liquid components (moisture and fat) and other volatiles. The losses were more with deep fat frying (DF). This could be the reason why the interaction between frying methods and frying times were significant ($p < 0.05$), suggesting that the differences cancel by the frying methods were different at different frying times. Hence, it could be deduced from the result that frying for 4 min yielded mean values of 73.85 % and 56.60 % for AF and DF, respectively with a mean difference of 17.25 %. While frying for 8 min yielded 62.43 % (AF) and 52.69 % (DF) with a mean difference of 9.74 %; frying for 12 min yielded 53.43 % (AF) and 46.89 % (DF) with a mean difference of 6.54 % and frying for 16 min yielded 47.30 % (AF) and 43.83 % (DF) with a difference of 3.47 %. Therefore, longer frying times appeared to equalize the differences in yield due to the two frying methods (AF and DF).

The results also showed that the mean cooking yields decreased significantly ($p < 0.05$) with frying temperatures and frying times. Hence, the interaction of frying temperature and time was significant ($p < 0.05$). Samples cooked at 170 ^{0}C, 180 ^{0}Cand 190^{0}C for 4 min had significantly ($p < 0.05$) the highest yields compared to other frying times, whereas samples cooked at 170 ^{0}C, 180 ^{0}C and 190 ^{0}C for 16 min had significantly ($p < 0.05$) the least cooking yields compared to other frying times. Kiran (2014) studied cooking yield in spent hen meat and reported that changes in cooking yield with cooking temperature and time were as results of moisture and fat losses. Hearne *et al.* (1978) similarly reported that cooking yield reduction with cooking temperatures and times was due to cook drip and evaporative loss. Table 2 shows rate of changes in cooking. Although overall interaction (Method x Temp. x Time) was not found significant, it is shown on Fig 1 that both cooking method and cooking temperature depend on cooking time. The interaction plots of cooking yield are shown in Fig. 1. The nature of this depending appears to be quadratic showing that all products lost moisture and it was rapid at the initial frying period (0 – 8 min), but slowed down on prolonged cooking (12 – 16 min). Table2 showed that DF fried samples, had lower yields compared to AF and at 170 ^{0}C there were higher yields than at 180 ^{0}Cand 190 ^{0}C

Frying	**Frying**				**Frying time (min)**			**Mean**
Method	temp. °C	0	4	8	12	16	Frying temp	Frying time
AF	170	100	78.33±0.49	67.06 ±0.11	58.47±1.03	51.52±0.58	63.85±10.71	
	180	100	72.26 ±0.50	63.04±0.20	53.26 ±1.39	45.34±0.07	58.48±10.84	
	190	100	70.97 ±0.81	57.19±0.45	48.56 ±0.88	45.03±0.21	55.44±10.69	
Mean		100	73.85±3.55	62.43±4.45	53.43±4.51	47.30±3.28	59.26±4.26	59.26±4.26
DF	170	100	58.89±0.87	53.25±1.12	47.99 ±1.23	45.78±0.55	51.48±5.47	
	180	100	56. 55 ±0.42	52.87 ±0.88	46.73±0.96	43.40 ±0.78	49.89±5.52	
	190	100	54.37 ±0.68	51.95±0.14	45.94±0.64	42.31±0.54	48.64±5.12	
Mean		100	56.60±2.09	52.69±0.88	46.89±1.19	43.83±1.66	50.00±1.42	50.00±1.42
	Grand mean	100	$65.23^{a}\pm9.43$	$57.56^{b}\pm5.93$	$50.16^{c}\pm4.65$	$45.57^{d}\pm3.07$	54.63±6.55	54.63±6.55

Data are means of duplicate determinations ± standard deviations.

Values with different superscripts on the same row are significantly different ($p < 0.05$)

AF- air frying

DF - deep fat fry

Fig.1: Showing depending of yield on cooking time

Table 2: Showing rate of change of cooking yield with cooking temperature

Cooking method	Cooking temperature (□)	Rate of change
AF	170	-3.06
	180	-3.42
	190	-3.44

Mean		-3.31
DF	170	-3.39
	180	-3.44
	190	-3.61
Mean		-3.48

AF- air frying

DF- deep fat fry

3.2. COOKING LOSS OF CHICKEN BREAST MEAT

The cooking loss of chicken breast meat with different methods each at170, 180 and 190 ^{0}C for 0, 4, 8, 12 and 16 min ar3e shown in Table 3, respectively. Results in Table 3 showed that cooking increased the loss of chicken breast muscle. On the average, cooking loss increased to an overall mean of 45.09 %. The increment in loss with cooking could be attributed to protein denaturation and cross shrinkage, leading to release of moisture and other volatiles as well as fat dripping or fat leaching into the cooking oil.

Cooking methods significantly, ($p < 0.05$) affected loss. Table 3 showed that samples cooked by air frying (AF) loss on the average, 40.70 % and deep fat frying (DF) 49.47 %. The differences in loss due to cooking methods were significant ($p < 0.05$) The lower yield of DF compared to AF could be attributed to more fat soluble substances leaching into the frying oil, in addition to loss of moisture. It is also possible that penetrating oil replaced the moisture in the DF samples causing lighter weight. It is known that oil has lower density (less weight per unit volume) compared to water. Consequently, the more the oil in the product, the less the weight.

Cooking temperature significantly ($p < 0.05$) affected yield. As shown in Table 3, cooking at 170 □ gave average loss of 41.80 %, at 180 □, average loss was 45.22 % and at 190 ^{0}C, average yield was 47.49 %. Thus, loss significantly ($p < 0.05$) increased with increase in cooking temperature. The differences in loss caused by cooking temperatures were significant ($p< 0.05$). Cooking at170^{0}C resulted to significantly ($p < 0.05$) lower loss than cooking at 180 □ and 190 □. This is similar to the report by Combes *et al*. (2003); Obuz *et al*. (2003); Garcia-Segovia *et al*. (2007) and Yancey *et al*. (2011) who revealed that lower cooking temperature resulted to lower losses.

Cooking Method	Cooking Temp. ^{0}C	Cooking time (min) 4	8	12	16	Mean -
AF	170	21.53±0.40	32.27 ± 0.27	41.33 ± 0.92	47.75 ± 0.14	
	180	27.32 ± 0.47	36.51 ± 0.78	46.43 ± 1.16	52.78 ± 0.20	
	190	28.53 ± 0.44	42.77 ± 0.44	51.14± 0.59	54.04 ± 0.35	
Mean		27.79 ±3.37	37.18 ± 4.74	46.30 ± 4.47	51.52 ± 2.98	40.70 ^{b}±10.45
DF	170	40.12±0.53	46.25 ± 1.00	51.36 ± 0.76	53.77 ± 0.28	
	180	43.08 ± 0.45	46.80 ± 1.27	52.53 ± 0.83	56.26 ± 0.49	
	190	45.18 ± 0.84	47.53 ± 0.13	53.38 ± 0.83	57.36 ±0.66	
Mean		47.79 ± 2.33	46.86 ± 0.92	52.42 ± 1.10	55.80 ± 1.69	49.47 ^{a} ±5.33
	Grand mean	37.79 ^{d}±2.85	42.02 ^{c}±0.96	49.36 ^{b}±2.79	53.66 ^{a}±2.34	45.09±7.89

Data are means of duplicate determinations ± standard deviations.

Values with different superscripts row- wise and column- wise differ significantly ($p < 0.05$)

AF air frying

DF deep fat frying

The increment of cooking loss with increasing temperatures could be attributed to higher rate of loss of moisture and other volatiles, higher rate of drip loss as globules are disrupted as well as higher rate of leaching of fat-soluble substances in the frying oil. The interaction between cooking methods and temperatures was found to be significant ($p < 0.05$), suggesting that loss caused by different cooking methods were different at different cooking temperatures. It could be deduced from Table 3 that the differences in loss between AF and

DF (AF – DF) samples increased with increase in cooking temperatures. From this interaction, it is deduced that DF method resulted to higher loss at each cooking temperature compared to AF method, with the DF method causing the highest loss at190 ^{0}C cooking temperature. This may suggest that, in addition to moisture loss, more fat-soluble substances in meat leached into the frying oil with the leaching being higher at higher temperatures. Although all products continued to loss high as temperature of cooking increased.

The results in Table 3 showed that cooking time affected loss. The loss at 4 min averaged 37.79 %, loss at 8 min averaged 42.02 %, loss at 12 min averaged 49.36 % and loss at 16 min averaged 53.66 %. Thus, loss significantly ($p < 0.05$) increased as cooking time increased. The differences are attributed to longer residence time the products had to stay in the cooking medium. The interaction between the cooking methods and cooking times was found to be significant ($p < 0.05$). This suggests that the losses due to the cooking methods were different at different cooking times. The significant interaction ($p < 0.05$) showed that the differences in loss between AF and DF (AF – DF) were decreasing with increase in cooking times. The results showed that the interaction between cooking temperatures and cooking times was not significant ($p > 0.05$). This suggests that the differences in loss caused by the temperature were similar at each cooking time. However, the overall interaction (Method x Temperature x Time) was found to be significant. This significant ($p < 0.05$) overall interaction confirmed why the products fried with vegetable oil (DF) at 190 ^{0}C and 16 min had the highest loss (57.36 %), while the products obtained by air frying(AF) at 170 ^{0}C for 4 min had the least cooking loss (21.53 %).

3.3. Changes in Fat Content of the Cooking Methods

The changes in fat content of chicken breast meat cooked with different methods each at170, 180 and 190 ^{0}C for 0, 4, 8, 12 and 16 min are shown in Table 4. The results in Table 4 showed that cooking increase the fat content of chicken breast meat. On the average, fat content increased to an overall mean of 9.31%. The increase in fat content of chicken breast meat treated with different cooking methods could be attributed to water dehydration effects of heat and concentration of dry matters as reported by Achir *et al.* (2009) and Hussain *et al.* (2013).

Cooking methods significantly, ($p < 0.05$) affected fat content. It was observed in Table 4 that samples cooked by air frying (AF) had an average fat content of 6.74 % and deep fat frying (DF) had 11.88 %. These higher fat contents were due to high fat level absorption of frying oil by the chicken samples and it increased with duration of frying time. There were statistically significant differences ($p < 0.05$) in fat content between AF and DF with cooking time.

Cooking temperature significantly, ($p < 0.05$) affected fat content of cooked chicken breast meat. Cooking at 170^0C gave average fat content of 8.43%, at 180^0C, average fat content was 9.44 % and at 190^0C, average fat content was 10.06 %. Thus, fat content significantly ($p < 0.05$) increased with increase in cooking temperature. The differences in fat content caused by cooking temperatures were significant ($p < 0.05$). Cooking at170 □ resulted to significantly ($p < 0.05$) lower fat content than cooking at 180 ^{0}C and 190 ^{0}C.

Table 4: Fat content (%) of chicken meat at different cooking method, temperature and time

Cooking	Cooking			Cooking time (min)			Mean
Method	Temp. ^{0}C	0	4	8	12	16	
AF	170	4.26 ±0.78	5.88±1.27	6.13 ± 1.20	6.37 ± 1.22	6.78 ± 0.20	
	180	4.26 ±0.78	6.23 ± 0.54	6.86 ± 1.37	7.89 ± 1.29	9.31 ± 0.52	
	190	4.26 ±0.78	6.58 ± 1.05	7.51 ± 0.76	9.17 ± 0.61	9.60 ± 1.30	
Mean		4.26 ±0.61	6.23 ± 1.01	6.83 ± 1.08	7.81 ± 1.51	8.56 ± 1.53	6.74^b± 1.87
DF	170	4.26 ±0.78	10.37 ± 0.21	12.06 ± 0.05	13.46 ± 0.51	14.71 ± 0.74	
	180	4.26 ±0.78	10.63 ± 0.11	13.76 ± 0.60	14.82±0.11	16.34 ± 1.34	
	190	4.26 ±0.78	12.92 ± 0.47	13.99 ± 0.58	15.81 ± 0.00	16.54 ± 0.70	
Mean		4.26 ±0.61	11.31± 1.28	13.27 ± 1.02	14.70 ± 1.25	15.86 ± 1.17	11.88^a ± 4.29
	Grand mean	4.26^e± 0.61	8.77^d± 1.15	10.05^c± 2.10	11.26^b± 1.38	12.21^a±1.35	9.31±3.08

Data are means of duplicate determinations ± standard deviations.

Values with different superscripts row- wise and column- wise differ significantly ($p < 0.05$)

AF air frying, DF deep fat frying

. The increases of fat content with increasing temperature could be attributed to concentration of dry matters. The interaction between cooking methods and temperatures was not significant ($p > 0.05$), suggesting that the differences in fat content caused by the temperatures were similar at each cooking temperature

The results in Table 4 showed that cooking time affected fat content. The fat content at 4 min averaged 8.77 %, fat content at 8 min averaged 10.05 %, fat content at 12 min averaged

11.26% and fat content at 16 min averaged 12.21 %. Thus, fat content significantly ($p < 0.05$) increased as cooking time increased. The differences are attributed to long time exposition of the products in the cooking medium. The interaction between the cooking methods and cooking times was found to be significant ($p < 0.05$). This suggests that the fat content due to the cooking methods were different at different cooking times. The significant interaction ($p < 0.05$) showed that the differences in fat content between AF and DF (AF – DF) were increasing, respectively with increase in cooking times. The results showed that the interaction between cooking temperatures and cooking times were significant ($p < 0.05$), suggesting that the differences in fat content between 170 and 180 ^{0}C (170 - 180 ^{0}C) or between 180 and 190 ^{0}C (180 - 190 ^{0}C) were neither increasing nor decreasing with increase cooking times. On the other hand, the differences in fat content between 170 and 190 °C (170 - 190 °C) were increasing with increase in cooking times. However, the overall interaction (Method x Temperature x Time) was not significant.

3.4. Tenderness of chicken breast meat

The compression force or hardness (kg/F) of chicken breast muscle cooked by AF and DF methods at temperatures of 170 ^{0}C, 180 ^{0}Cand 190 ^{0}C for 0, 4, 8, 12 and 16 min are shown in Table 5. Table 5 showed an overall hardness value of 12.29 kg/F. The increase in hardness of samples cooked by Air frying (AF) and deep fat frying (DF) dry heat cooking could be attributed to softening and alterations of collagen and connective tissues to gelatine and shrinkage of muscle fibers of the products and these have resulted to an overall softness of 87.71kg/F.

The AF and DF fried samples had different hardness values at 170 ^{0}C, 180 ^{0}C and 190 ^{0}C for 4 min 8.09-and10.09 kg/F, 10.16-and10.95kg/F, 9.45 and 10.61 kg/F respectively. These results showed that cooking significantly increased ($p < 0.05$) the tenderness of chicken breast meat up to a certain point, before it overturned. Heat application in chicken breast meat resulted in softening of connective tissues triggered by alteration of collagen to gelatin and increasing frying temperature resulted in denaturation and coagulation of proteins, shortening and hardening of the muscle as well as increases toughness as reported by Dawson *et al.* (1991). Moreover, heat causes an induced structural change in meat due to shrinkage of intramuscular collagen, the shrinkage and denaturation of actomyosin (Wattanachant *et al.*, 2005; Li *et al.*, 2013). This finding agrees with studies conducted by Lin *et al.* (2000), Pandey *et al.* (2014) and Lorenzo *et al.* (2015). The texture of air-fried samples increased between 170 ^{0}Cand 180 ^{0}Cand decreased at190 ^{0}C, whereas DF treated samples increased at170 ^{0}C and decreased in values between 180 ^{0}C and 190 ^{0}C. It was also observed that AF samples had lower mean hardness value(12.39 kg/F) when compared with DF samples (12.18 kg/F) at170 ^{0}C, 180 ^{0}C and 190 ^{0}C Therefore, it is reasonable to conclude that AF samples had lower hardness as well as better tenderness than DF cooked samples.

The hardness values in the frying methods AF and DF at 170 ^{0}C for 8, 12 and 16 min were 10.53and 13.69 kg/F; 17.26 and16.51 kg/F; 20.43 and 18.89 kg/F, respectively. The mean hardness values for the frying times showed that AF samples had higher value of 11.27kg/F when compared with DF samples, which had a value of 11.10 kg/F. An Increase in frying time of chicken breast meat resulted in denaturation of proteins. It also leads to decrease in the amount of bound water in the tissue system and increase meat toughness or hardness (Palka, 2003; Obuz *et al*., 2004; Tornberg, 2005, Nikmaram *et al*., 2011).The interactions of frying temperature and frying time (Temp x Time) were significantly ($p < 0.05$).

The analysis of variance results of hardness of chicken breast meat samples showed that hardness of chicken breast meat samples increased significantly ($p < 0.05$) as frying temperature and frying time increased. The main effects of frying temperature (Temp) and frying time (Time) and their interactions were significantly different ($p < 0.05$). Moreover, the interactions of frying method, frying temperature and frying time were statistically significant ($p > 0.05$). This significant ($p < 0.05$) overall interaction confirmed why the products deep fat fried (DF) at 190^{0}C and 16 min had the least hardness content (7.37 kg/F), while the products obtained by air frying (AF) at 170^{0}C for 16 min had the highest hardness content (20.43 kg/F). The interaction plots of hardness with hardness are shown in Fig. 2. The plots showed an interconnecting of cooking methods with texture/hardness of cooked meat. Table 6 showed the rate of changes of hardness with cooking temperatures. The DF fried samples, had lower rate of changes in textures compared to AF in the cooking temperatures.

Frying	Frying			Frying time (min)			Mean	
Method	temp. ℃	0	4	8	12	16	Frying temp	Frying method
AF	170	6.79±0.96	8.09±0.10	10.53±0.07	17.26 ±0.21	20.43±1.15	14.08 ±5.33	

	180	6.79±0.96	10.16 ±0.49	13.53±1.51	13.30±1.08	12.70±0.70	12.47±1.63	
	190	6.79±0.96	9.45 ±1.29	11.67±0.28	10.88±1.48	10.66 ±0.75	10.67±1.17	
Mean		6.79±0.96	9.23±1.13	11.91±1.52	13.81±2.99	14.60±4.65	12.39±3.45	12.39±3.45
DF	170	6.79±0.96	10.09 ±1.22	13.69 ±1.09	16.51±0.81	18.89±0.70	14.79±3.58	
	180	6.79±0.96	10.95±0.40	12.52 ±0.54	12.95±1.60	13.43±1.86	12.46±1.38	
	190	6.79±0.96	10.61±0.69	9.71±0.55	9.48±1.32	7.37±1.65	9.29 ±1.54	
Mean		6.79±0.96	10.55±0.76	11.97±1.92	12.98±3.30	13.23±5.28	12.18±3.24	12.18±3.24
	Grand mean	6.79±0.96	9.89^{c}±1.14	11.94^{b}±1.65	13.40^{a} ±3.03	13.92^{a} ±4.80	12.29±0.20	12.29±0.20

Data are means of duplicate determinations ± standard deviations.

Values with different superscripts on the same row are significantly different ($p < 0.05$)

AF- air frying

DF- deep fat frying

Fig.2: Showing depending of hardness on cooking time

Table 6: Showing rate of change of texture (hardness) with cooking temperature

Cooking method	Cooking temperature (□)	Rate of change
AF	170	0.85
	180	0.37
	190	0.24
Mean		0.49
DF	170	0.76
	180	0.39
	190	0.04
Mean		0.40

Temp - Frying temperature

Time - frying time

3.5. Changes in Sensory Texture.

Table 7 showed results of samples cooked at170, 180 and 190 ^{0}C for 8, 12 and 16 min. Samples cooked for 4 min were light pinkish in appearance and were not pleasing to consumers for assessment. The results in Table 7 showed that cooking reduced texture scores of cooked chicken breast meat. On the average, texture scores of chicken breast meat reduced to an overall mean of 6.32. Cooking methods affected texture scores of cooked chicken breast meat. The DF cooked samples had significantly ($p < 0.05$) higher textural scores compared to samples cooked by AF method and rated 'moderately crispy'. The higher DF method texture scores were due to higher collagen solubilisation effects by higher oil frying temperature. The finding agrees with findings by Hus and Yu (1999), Hsu, and Chung (1998) who reported DF as better meat products for its crispy texture.

There were no significant differences ($p < 0.05$) in the texture scores of chicken breast meat cooked at the cooking temperatures of 170, 180 and 190 ^{0}C. However, samples cooked at 170 ^{0}C and 180 ^{0}C were rated 'slightly crispy', samples cooked at 190 ^{0}C were rated as 'moderately crispy'. The increases in the texture scores between 170 ^{0}C, 180 ^{0}C and 190 ^{0}C were due to an increase in the denaturation of myosin and collagen as reported by Garcia – Segovia *et al.* (2007) and Khan *et al.*, (2014). The increases in texture scores of samples cooked between 180 ^{0}C and 190 ^{0}C were due to hardening of meat due to moisture evaporation from it.

. Generally, cooking at 180^{0}C for 8, 16 and 12 min reduced the texture of cooked chicken breast meat but cooking at 190^{0}C increased the texture scores at 170^{0}C. The texture scores of samples cooked at 170°C for 8 and 16 min were not significantly different ($p > 0.05$) with samples cooked at 180°C for 8 and 16 min and each rated neither crispy nor soft and slightly crispy, respectively. However, samples cooked at 190^{0}C for 8 and 16 min had significantly ($p < 0.05$) higher texture scores than samples cooked at 170 and 180^{0}C for 8 and 16 min. and rated each 'slightly crispy' and 'moderately crispy', respectively. Meanwhile, samples cooked at 170 ^{0}C, 180 0C for 12 min were not significantly different ($p > 0.05$), and each rated 'slightly crispy'. The results of overall mean texture score showed that texture scores increased with cooking time and samples cooked 16 min had the highest score than other cooking times but 8 min and 12 min cooked samples were each rated 'slightly crispy' and 16 min cooked samples rated 'moderately crispy nor'

Table 7: Changes in Texture Description of chicken breast meat

	Cooking temp (℃)	Cooking time (min)	Scores	Description category
AF	170	8	4.75^{b}±1.92	Neither crispy nor soft
		12	5.35^{b} ± 1.31	Slightly crispy
		16	6.25^{ab} ± 2.17	Slightly crispy
	180	8	4.65^{b} ± 1.70	Neither crispy nor soft
		12	4.75^{b}± 1.77	Neither crispy nor soft
		16	5.95^{a} ± 1.05	Slightly crispy
	190	8	5.35^{b} ± 2.49	Slightly crispy
		12	6.02^{b} ± 1.81	Slightly crispy
		16	6.00^{b} ± 1.75	Slightly crispy
mean		*	5.45 ± 0.63	Slightly crispy
DF	170	8	6.50^{a}± 1.67	Moderately crispy
		12	6.90^{a} ± 1.94	Moderately crispy
		16	7.20^{a} ± 1.96	Moderately crispy
	180	8	6.95^{a}±1.57	Moderately crispy
		12	7.00^{a} ± 1.41	Moderately crispy
		16	7.60^{a}± 0.94	Very much crispy
	190	8	7.05^{a}± 1.54	Moderately crispy
		12	7.20^{a} ± 1.64	Moderately crispy
		16	8.35^{a} ± 0.81	Extremely crispy
Mean		*	7.19±0.53	Moderately crispy
Grand		**	6.32 ± 1.23	Moderately crispy

mean

Data are means of twenty determinations ± standard deviations.
Values with different superscripts I the same column differ significantly ($p < 0.05$).
AF - air frying and DF - deep fat frying

4. Conclusion

Frying results in migration of water from meat crust into frying oil as steam, causing increased internal pressure to move water from core meat to replace the migrated water. The moisture loss and oil uptake during chicken breast meat frying processes results in cooking yield reduction increases in cooking loss and changes in tenderness of the products. Air fried (AF) samples had more cooking yield value 59.26 ± 4.26 % and less cooking loss 40.20±4.23 % than deep fat fried (DF) sample values of 50.00±1.42 and 49.47±1.50; increasing cooking temperature and time decreased and amplified the cooking yield and loss in the frying methods.

Similarly, cooking increased the tenderness of chicken breast meat, but prolonged cooking time decreased tenderness values of the frying methods. Air fried (AF) samples had higher mean hardness value of 12.39±3.45 kg/F in cooking times than DF value 12.18±3.24 kg/F. Chicken breast meat samples fried by AF and DF methods at 170 ^{0}C for 16 min had highest and best tenderness value of 20.43 Kg/F and 18.89 Kg/ F respectively. This study indicated that frying times increased the tenderness more than the frying temperature. The results of the relationship between hardness and sensory texture scores showed there were no significant differences ($p > 0.05$) in samples cooked by AF and DF methods. Moreover, the results of texture assessment through hardness and sensory showed that hardness values gave better reflection of texture than sensory scores. However, Air fried (AF) samples are better in cooking chicken breast meat considering cooking yield and losses. Heat emanating from frying process exerted increased internal pressure on muscle fibres and squeezed much more water from DF fried samples.

References

Achir N, Vitrac O, Trystram G (2009). Heat and mass transfer during frying. In Advances in Deep Fat Frying of Foods, (Sahin S, Sumnu SG, eds.), CRC Press, New York, pp. 115- 142.

Andres, A., Arguelles, A., Castillo, M. L. and Heredia, A. (2013). Mass transfer and volume Changes in French fries during air frying. *Food Bioprocess Technology* 6:1917 – 1924.

AOAC (2010). Official methods of Analysis (18th edition) Association of Official Analytical Chemists, Washington D.C.

Bindon, B. and Jones, N. (. 2001). Cattle supply, production systems and markets for Australian
Beef. *Australian Journal of Experimental Agriculture*, Vol.41, 861 - 877
Bordin, K., Kunitake, M. T., Aracava, K. K., Favaro- Trindade, C. S. (2013). Changes in Food caused by deep fat frying. *A review. Arch Latinoam Nutrition* 63 (1):5 – 13.
Bourne, M. C. (1978). Texture profile analysis. *Food Technology,* 32, 62 – 66.
Bourne, M.C. (2002). Food texture and viscosity: concept and measurement Academic Press. An *Elsevier Science Imprint, New York. Pp. 175 - 253*
Combes, S., Lepetit, J., Darche, B. and Lebas, F. (2003). Effect of cooking temperature and time on Warner-Bratzler tenderness measurement and collagen content in the rabbit Meat. Meat Science 66:91 – 96
Dawson, P. L., Sheldon, B. W. and Miles. J. (1991). Effect of aseptic processing on the Texture of chicken meat. Poultry Science, 70: 2359-2367.
Dobarganes, C., Marquez- Raiz, G. and Velasco, J. (2000). Interactions between fat and food During deep-frying. *European Journal of Lipid Science and Technology*102:521 – 552
García-Segovia, P., Andrés-Bello, A., Martnez-Monzo, J. (2007). Effect of cooking method on
Mechanical properties colour and structure of beef muscle (Pectorals), *Journal of Food Engineering* 80 (3):813-821
Giovanelli, G., Torri, L., Sinelli, N., Buratti, S. (2017). Comparative study of physio -chemical and sensory characteristics of French fries prepared from frozen potatoes using different cooking systems. *European Food Resources Technology*. DOI 10.1007/s00217- 017-2870-x
Haizam, A., Tamizi, A. and Ismail, R. (2008). Comparison of the frying stability of standard Palm olein and special quality palm olein. *Journal of American Oil Chem*. Soc.85:245 - 251.
Hearne, L. E, Penfield, M, P and Goetz, G. E. (1978). Heating effects on bovine Semitendinosus: Shear, muscle fibre measurements, and cooking losses. *Journal of Food Science* 43: 10 - 14
Hubbard, L. J and Farkas, B. E. (1999). A method for determining the convective heat transfer
Coefficient during immersion frying. *Journal of Food Process Engineering* 22: 201 – 214
Hussain, A. I., Chatha, S. I. S., Arshad, T. M., Adzahoor, A. and Afzal, S. (2013). Comparative
Study of different cooking methods on nutritional and fatty acid profile of chicken meat. Journal of Chemical Society of Pakistan Vol. 25 (3):678 – 684.
Hsu, S. Y. and Chung, H. Y. (1998). Effect of processing factors on qualities of emulsified Meatballs. *Journal of Food Engineering* 36: 337 – 347
Hsu, S. Y. and Yu, S. H. (1999). Effects of phosphate water, fat and salt on qualities of low Fat emulsified meatball. *Journal of Food Engineering* 39: 123 – 130
Ihekoronye, A.I. and Ngoddy, P. O. (1985). Integrated Food Science and Technology for the Tropics, Macmillan, London and Basingstoke.
Iwe, M. O. (2002). Hand Book of Sensory Methods and Analysis. Rojoint Communication Services Ltd., Uwani Enugu
Khan, M. A., Ali, S., Abid, M., Alimad, H., Zhang, L., Tume, R. K., Zhou, G. (2014). Enhanced texture, yield and safety of a ready to eat salted duck meat product using a high pressure-heat process. *Food Science Engineering Technology* 21: 50 – 57.
Krokida, M. K., Oreopolou, V. and Maroulis, Z. B. (2000). Water loss and oil uptake as a

Function of frying time. *Journal of Food Engineering* 44: 39 – 46.

Li, C., Wang, D., Xu, W., Gao, F. and Zhou, G. (2013). Effect of final cooked temperature on Tenderness, protein solubility and microstructure of duck breast muscle. LWT – *Food Science and Technology* 51: 266 – 274.

Lin, S., Huff, H. E. and Hsieh, H. (2000). Texture and chemical characteristics of soy protein Meat analog extruded at high moisture. *Journal of Food Science* 65 (2): 264 – 269.

Lorenzen, J. M., Cittadini, A., Munekata, P. E. and Dominguez, R. (2015). Physicochemical Properties of focal meat as affected by cooking methods. *Meat Science* 108: 50 – 54.

Moreira, R. G., Sun, X. and Chen, Y. (1997). Factors affecting oil uptake in tortilla chips in Deep fat frying. *Journal of Food Engineering* 31, 485 – 498.

Moreira, R. G., Castell-Perez, M. E and Barrulet, M. A. (1999b). Oil absorption in fried Foods. In: Deep- fat frying; fundamentals and applications, Gaithersburg, Md: Chapman &Hall Food Science Book p. 179- 221.

Obuz, E., Dikeman, M. E. and Loughlin, T. M. (2003). Effects of cooking methods, reheating, Holding time and holding temperature on beef longissimus lumborum and Biceps Femoris Tenderness. *Meat Science* 65: 841 – 851

Obi, I.U. (2013). Introduction to Factorial Experiments for Agricultural, Biological and Social Sciences Research (3rd edition). Optimal Computer Solutions Ltd., Enugu

Obuz, E., Dikeman, M. E., Grubel, J. P., Stephens, J. W. and Loughlin, T. M. (2004). Beef *Longissimus lumborum* biceps femoris and deep pectoralis Warner– Bratzler shear Force is affected differently by endpoint temperature, cooking method and USSDA quality grade. *Meat Science* 68: 243 – 248.

Palka, K. (2003). The influence of postmortem aging and roasting on the microstructure, Texture and collagen solubility of bovine semitendinosus muscle. *Meat Science*64:

Pandey, M. C., Harilal, P. T and Radhakrishna, K. (2014). Effect of processing conditions on Physio -chemical and textural properties of shami kebab. *International Food Research Journal* 21 (1): 223 – 228.

Pathare, P. B. and Roskilly, A.P. (2016). Quality and energy evaluation in meat cooking. *Food Engineering Review* 8: 435 – 447.

Pinthus, E. J., Weinberg, P. and Saguy, I. S. (1995). Oil uptake in deep fat frying as affected By porosity. *Journal of Food Science* 60 (4): 767 -721

Saguy, S. and Dana, D. (2003). Integrated approach to deep fat frying engineering, nutrition, Health and consumer aspects. *Journal of Food Engineering* 56: 143–152

Sahin, S., Sastry, S. K. and Bayindirili, L. (1999). Heat transfer during frying of potato slices. *Journal of Lebensmittel-Wissenschaft and Technologies* 29: 19–24.

SPSS (2015). Statistical Package for Social Science Research (SPPSS version 23.0) Inc., Chicago.

Tornberg, E. (2005). Effects of heat on meat proteins – Implications on structure and quality of meat products. *Meat Science* 70: 493 – 508.

Wang, D., Dong, H., Zhang, M., Liu, F., Bian, H., Zhu, Y and Xu, W. (2013). Changes in actomyosin dissociation and endogenous enzymes activities during heating and their relationship with duck meat tenderness. *Food Chemistry* 141:675 – 679

Wattanachant, Bengkulu, S. and Ledward, D. A. (2005). Effect of heat treatment on changes In texture, structure and properties of Tai indigenous chicken muscle. *Food Chemistry* 93:337- 348.

Yancey, I. W. S., Wharton, M. D. and Apple, J. K. (2011). Cooking method and end point Temperature can affect the Warner-Bratzler shear force, cooking loss, and internal Cooked color of beef longissimus steaks. *Meat Science* 88: 1 – 7.

Zhang Q, Saleh ASM, Chen J, Shen Q (2012). Chemical alterations taken place during deep fat frying based on certain reaction products: A review. *Chem Phys Lipids*. 165(6): 662-681