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# Impact of Cooking Conditions on Proximate Composition and Textural Properties of Chicken Breast Meat

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***Authors' contributions***

*This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.*

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## ABSTRACT

The aim of this study was to evaluate the impact of cooking conditions on proximate composition and textural properties (cohesiveness and chewiness) of chicken breast meat. Eight packs of industrial skinless chicken breast meat were cooked by air frying (AF), baking (BK), deep fat frying (DF) and grilling (GR) at 170, 180 and 190°C for 0, 4, 8, 12 and 16 min. The chicken breast packs were frozen and sliced into dimensions, thawed, cooked and analysed by a two way analysis of variance. The results revealed that cooking methods significantly ($p < 0.05$) decreased moisture and protein contents from 75.14 to 58.25 % and 89.17 to 82.98 %, but increased fat content from 4.26 to 7.78 %, ash content from 1.95 to 2.39 %, carbohydrate content from 4.63 to 6.95 %, cohesiveness content from 0.40 to 0.52 and chewiness value from 3.63 to 6.05 kg. An increases in cooking temperatures and times decreased moisture content from 60.58 to 56.34 % and 75.14 to 47.40 % and protein content from 83.77 to 82.11 % and 89.17 to 79.45 %. Similarly, increases in

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cooking temperatures and times significantly ($p < 0.05$) increased fat content from 7.00 to 8.44 % and 4.26 to 10.12 %, ash content from 2.15 % to 2.59 % and 1.95 to 2.67 %. This study showed that increases in cooking temperatures decreased non-significantly ($p > 0.05$) carbohydrate content from 7.02 to 6.92 %, but increases in cooking times increased carbohydrate content from 4.63 to 7.76 %. An increases in cooking temperatures and times increased cohesiveness content from 0.50 to 0.54 and 0.40 to 0.63, chewiness value from 5.50 to 6.77 kg and 3.63 to 8.54 kg, respectively. There were no significant differences ($p > 0.05$) in chewiness values of samples cooked by AF and GR methods. The best cooking method/ temperature / time for low nutrient losses was BK, 170$^{o}$C and 4 min.

*Keywords: Chicken breast; cooking conditions; proximate composition; cohesiveness; chewiness.*

## 1. INTRODUCTION

Meat is nutrient rich commodity which are derived from skeletal muscle and organ tissues of food animal. It is composed of about 40 % weight of the animal as reported by Xiong [1]. Chicken breast is special muscle with less application in birds' physical activity and birds with increased growth rate have heavier breast muscle with thick fiber. It is leaner (< 3g fat/100g) than other muscles as well as supplies higher quality protein with mild flavour, versatility and other essential nutrients for the healthy living of consumers. Chicken has also no religious discrimination, low content of saturated fatty acids compared to other meat types. It has an increased consumption rate, low cholesterol, but good sources of essential amino acids and minerals elements as reported by Sharma and Sharma [2] and Riovanto et al. [3], Chumngeon et al. [4], Alugwu et al. [5] and Alugwu et al. [6]. It has been reported by Sharma and Sharma [2] to constitute on wet bases 74 % moisture, 23 % protein and 1.2 % fat. Chicken is a good sources of B- vitamins and trace elements, as well as contribute adequately to human micronutrients daily requirements Alugwu et al. [6]. The nutritional composition of chicken is influenced by variables like breed, feed, age, production method, sex and cooking method as reported by Kumar et al. [7].

Meat can be cooked with different cooking methods such as air frying (AF), baking (BK), deep–fat frying (DF) and grilling (GR). Cooking of meat results in weight reduction due to release of free, immobilized and bound water from proteins by dripping and evaporation as moisture and other volatile matters and melting of fats. These water losses from proteins (collagen, connective tissues and myofibrillar) can only occur through protein denaturation at different cooking temperature and time intervals. Heat denatures proteins which offer different quality attributes of tenderness, juiciness, flavor and appearance to cooked meat and produced palatable, digestible and microbiologically safe products. Cooking also improves the physical properties and eating quality attributes of meat. Meat is cooked prior to consumption to make it healthy and increased its nutrients bioavailability. Cooking results in sensory properties improvement of meat by softening the texture, increasing flavour and colour appeal Alugwu et al. [8] and aesthetic value, nutritive, technological and hygienic quality attributes of the cooked products. Cooking techniques have been reported by Tornberg [9] to affect structural changes and compositional components of cooked chicken. These techniques may results in loss of heme iron from myoglobin which increasing the possibility of lipid oxidation and leads to rancidity in the cooked products and other changes that occurred during cooking.

The proximate composition and textural method, which are conducted by instrumental methods could also be used to assess cooking changes of meat. Thermal processing reduces the values of chicken flesh nutrients depending on the cooking methods. The application of several cooking time and temperature has been reported during meat cooking by Alugwu et al. [10]. Besides, deep-fat frying is a rapid high-heat technique which produces golden coloured products and higher meat juicier products. Meat cooked by grilling results in a drier and a lower yield product compared with deep-fat frying. It has also been reported by Krokida et al. (2005) that meat cooked by deep fat frying have higher oil intake which causes changes in physical and chemical composition of its products. There is no much literature information on proximate composition and textural properties on cooked chicken breast. Hence, the aim of this study was to ascertain the effect of cooking conditions on proximate composition, cohesiveness and chewiness properties of chicken breast meat.

## 2. MATERIALS AND METHODS

### 2.1 Sample Preparation and Cooking Process

Eight packs of fresh, boned and skinless broiler chicken breast meat were selected from a local grocery at St. Anne-de –Bellevue, Montreal, Canada. These packs were transported to the Food and Bioprocess Laboratory, Dept. of Bioresource Engineering, Macdonald Campus of McGill University in less than 30 min under cool conditions. In the Laboratory, samples were frozen at -80 °C for 2 h to harden the muscle for easy slicing into 3.0 cm x 3.0 cm x 2.0 cm. The cut samples were divided into four cooking methods [air frying (AF), baking (BK), deep fat frying (DF) and grilling (GR)]. Each portion was divided into three different cooking temperature regimes (170, 180 and 190 °C) and each temperature was subdivided into five cooking times (0, 4, 8, 12- and 16-min).

Fifty grams of broiler chicken breast muscles was employed for each cooking experiment. The uncooked breast meat was used as the control sample. Samples for grilling and baking were done using a Black and Decker digital 4-in-1 oven (SKU: TO1303SU/ FABRICADO EN/ CHINA). Air frying was carried out with Philips Air fryer (Model HD 9220) and deep fat frying was done with Delonghi (Type: D24527 DZ, Made in China) equipment. These equipment were conditioned prior to use. All samples after cooking were allowed to cool for 30 min at room temperature, before analyses, wrapped in aluminum foil and packaged in Ziploc. The cooked and uncooked samples were kept in freezer waiting for subsequent analyses. All the cooking experiments were performed in duplicate and stored in freezer waiting for subsequent analyses.

### 2.2 Proximate Composition of Chicken Breast Meat

#### 2.2.1 Determination of moisture content

Moisture content of the samples was determined by the hot air oven method using standard methods of AOAC (2010). Moisture dish was cleaned and weighed ($W_1$). Five-gram of the samples was weighed into tarred moisture dishes ($W_2$). These samples were dried in a vacuum air oven at 105 °C for 24 h, removed from the oven and cooled in desiccators to a constant weight ($W_3$). The percentage moisture content calculated as shown in eqn.1

$$\text{Moisture Content (\%)} = \frac{W2-W3}{W2-W1} \times 100 \quad \text{Eqn.1}$$

Where:

$w_1$ =weight of empty moisture dish
$w_2$ = weight of moisture dish with sample prior to hot-air oven drying
$w_3$ = weight of moisture dish with sample after hot-air oven drying

#### 2.2.2 Freeze drying process and determination of protein content

The samples were placed in Ziploc bags and frozen. Thereafter, transferred to tin sample dishes, covered with paraffin and frozen again for two hours. The paraffin covered samples were perforated and loaded in freeze dryer (Thermos) and dried at-50 °C for three days. These frozen meat samples (raw meat, air fried, baked, deep fat fried and grilled) were ground with Cuisinart grinder to produce ground samples. A 50 mg of each of the sample was weighed into a tin foil cup, folded; sample identity coded in the Personal computer (PC) and introduced into auto sampler holes of VELP Dumas Nitrogen Analyzer NDA 701. The total nitrogen content of each sample was determined as described by Einarsson et al. [11] and Alugwu et al. [5].

These samples were heated at 800 - 1000 °C in the presence of pure oxygen and it resulted in the conversion of all nitrogen forms in the samples to nitrogen oxides and other bye-products such as carbon dioxide, water, nitrogen and several oxides (NxOy). The gas mixture combustion products was passed through hot copper to remove any oxygen and reduce other nitrogen oxides present to molecular nitrogen. Thereafter, passed through traps to remove water and carbon dioxide. The total nitrogen content from the samples was measured by thermal conductivity detector signals by thermal conductivity. The protein content of the samples obtained by multiplying total nitrogen by a conversion factor of 6.25.

#### 2.2.3 Determination of fat content

Fat content of the samples was determined by Soxtec method using standard methods of AOAC [12] six extracting cups and six thimbles. The ground meat sample (3g) ($W_1$) was weighed into previously weighed thimbles and the cups also weighed ($W_2$). Thereafter, the thimbles were attached to condenser of the extracting unit, while 50 mL of petroleum ether was added to each of the cups and each mounted on the extracting units.

The thimbles were immersed in the cup containing the petroleum ether - solvent and the set-up locked, water inlet opened, power source switched on and the valves connecting the cups and condensers closed, but at116 °C, an immersion timing of 30 min displayed and timing started. Thereafter, the thimbles were separated from the cups containing the solvent, indicator pointer shifted to washing. While valves connecting the cup and condenser set closed and washed for 45 min. Finally, the valves connecting the cup and condensers were opened to recover solvent and indicator pointer switched immediately to the recovery for 15 min. Thereafter, the cups were removed, cooled in desiccators and their contents reweighed ($W_3$) using eqn.2.

$$\text{Fat Content } (\%) = \frac{W_3 - W_2}{W_1} \times 100 \qquad \text{Eqn.2}$$

Where:

$w_1$ =weight of sample
$w_2$ = weight of empty cup
$w_3$ = weight of cup with fat

**2.2.4 Determination of ash content**

The ash content of the samples was determined by Muffle furnace using standard methods of AOAC (2010). The ground sample (2g) was weighed ($W_1$) into a crucible of known weight ($W_2$). The crucibles with the sample were placed in the Muffle furnace previously heated at 600 °C for 6 h to produce a clearly whitish ash. Thereafter, the crucibles were removed, cooled in a desiccator and reweighed ($W_3$). The ash content was calculated as shown in Eqn.3.

$$\text{Ash Content} = \frac{W_3 - W_2}{W_1} \times 100 \qquad \text{Eqn.3}$$

Where:

$w_1$ = weight of sample
$w_2$ = weight of crucible
$w_3$ =weight of crucible with ash

**2.2.5 Determination of carbohydrate of the samples**

The carbohydrate content of the samples was calculated by difference as described by AOAC (2010) as shown in eqn.4.

% Carbohydrate = 100 - % (Moisture + Protein + Fat + Ash). Eqn.4

## 2.3 Textural Assessment

Textural properties of the samples were performed with Texture Analyser (TA-XT2, Stable Micro Systems) using Texture profile analysis (TPA) and following the procedure of Bourne [13,14]. The cut, cooked and cooled samples were placed on the platform of the analyser which was connected to personal computer (PC) for logging in of the samples. Each of the samples was subjected to double (two fold) compression cycle with 50 mm probe and fitted into 25 kg load cell as a mimic of a jaw action to 75 % of their original height. The pre-test speed was 5 mm/s, test speed was1 mm/s, post-test speed was 5 mm/s, travel distance was 10 mm and exposure time was 5 sec.

The analyses were performed in duplicate on each sample and the resistance of the sample was plotted in a force- time (gram-sec) graph as shown in Fig. 1. These parameters were determined using software: Cohesiveness = extent to which sample could be deformed prior to rupture (A2/A1, A1= the total energy required for the first compression and A2 = total energy required for the second). Chewiness = amount of work used to masticate the sample for swallowing (Springiness x Hardness x Cohesiveness). Four measurements were taken in each sample.

## 2.4 Statistical Analysis

This research study was a 4 x 3 x 5 factorial experiment in a Completely Randomized Design (CRD). Each of the cooking methods of air frying (AF), baking (BK), deep-fat frying (DF) and grilling (GR) was treated in combination of batch of three cooking temperatures (170, 180 and 190 °C) and five cooking time intervals (0, 4, 8, 12 and 16 min). A total of 120 samples were collected and analysed by a two way analysis of variance (ANOVA) using IBM SPSS Statistics version 23.0 (IBM Corp. 2015) software package. The parameters measured were the proximate composition and textural properties. The significant differences between treatment means were determined by Duncan New Multiple Range Test (DNMRT) at ($p < 0.05$). Values were reported in results as means ± standard deviation (SD).

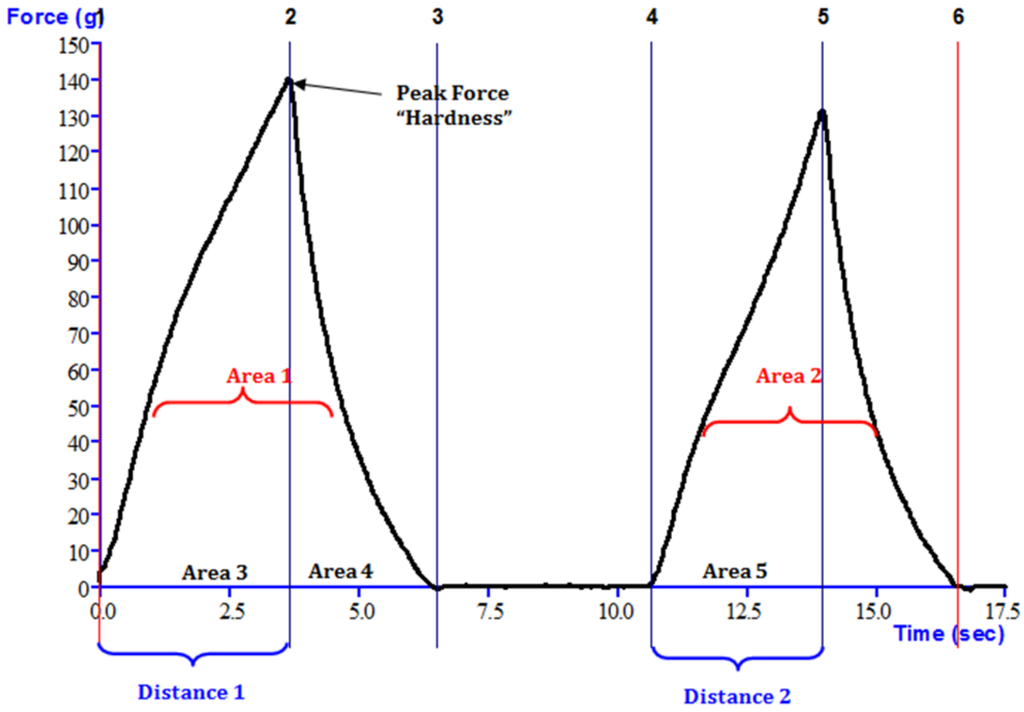


**Fig. 1. Force – time (gram-sec)**
*Source: Bourne [13]*

## 3. RESULTS AND DISCUSSION

### 3.1 Proximate Composition of Chicken Breast Meat

#### 3.1.1 Changes in moisture content

The results of changes in moisture content of chicken breast meat cooked with different methods each at170, 180 and 190 ℃ for 0, 4, 8, 12 and 16 min are shown in Table 1. Table 1 showed that cooking reduced the moisture content of chicken breast meat to an overall mean moisture content of 58.25 %. The reduction in moisture content of chicken breast meat treated with different cooking methods could be attributed to protein denaturation, release of water entrapped in the myofibrils and melting as well as release of fat as dripping or leaching into the cooking oil.

Cooking methods significantly ($p < 0.05$) affected moisture content. It was observed in Table 1 that samples cooked by air frying (AF) had an average moisture content of 56.71 %, those cooked by baking (BK) had 61.10 % and deep fat frying (DF) had 55.82 %, while grilling (GR) had mean moisture content of 59.37 %. The differences in moisture content due to cooking methods were significant ($p < 0.05$) and sample cooked by BK method had significantly ($p <0.05$) higher moisture content than others. The lower moisture content of DF compared to others could be attributed to higher melting of fatty soluble substances and leaching into the frying oil, in addition to coagulation of myofibrillar and sarcoplasmic proteins of muscle fiber by heat release and loss of moisture. This finding is not in line with reported findings by Rosa et al. [15] who reported that oven cooked chicken breast had higher water loss than DF cooked samples.

Cooking temperature significantly ($p < 0.05$) affected moisture content of cooked chicken breast meat. The table showed that cooking at 170 ℃ gave average moisture content of 60.58 %, at 180 ℃ average moisture content was 57.82 % and at 190 ℃, average moisture content was 56.34 %. The differences in moisture content caused by cooking temperatures were significant ($p< 0.05$). Thus, moisture content significantly ($p < 0.05$) reduced with increase in cooking temperature. Heat emanating from the cooking induced structural and compositional denaturation of proteins and causes; release of water held by capillary forces and bound to proteins as reported by Aaslyng et al. [16]. The reduction of moisture content with increased temperature could be attributed to higher rate of loss of moisture and melting losses of fats. The interaction between cooking methods and temperatures was not significant ($p > 0.05$), suggesting that the differences in moisture content caused by the temperature were similar at each cooking time. It could be deduced from Table 1 that the differences in moisture content between AF and DF (AF – DF) samples decreased with increase in cooking temperatures. On the other hand, the differences in moisture content between AF and BK (AF – BK) or between AF and GR (AF – GR) were neither increased nor decreased with increase in cooking temperatures, while the differences in moisture content between BK and DF (BK – DF), BK and GR (BK –GR) as well as DF and GR (DF – GR) were neither increased nor decreased, respectively with increase in cooking temperatures. From this interaction, it is deduced that DF method resulted to least moisture content at each cooking temperature compared to other cooking methods, with the DF method causing the least yield at 190 $^{o}$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 reduce in moisture content as temperature of cooking increased, baked (BK) products had the highest moisture content at each cooking temperature. This suggests that there was less fat drip loss and moisture loss at each temperature compared with other cooking methods.

The results in Table 1 showed that cooking time affected moisture content. The moisture content at 4 min averaged 61.16 %, moisture content at 8 min averaged 56.43 %, moisture content at 12 min averaged51.12 % and moisture content at 16 min averaged 47.40 %. Thus moisture content significantly ($p < 0.05$) reduced 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 ($p < 0.05$), suggesting that the yields due to the cooking methods were different at different cooking times. The significant interaction ($p < 0.05$) showed that the differences in moisture content between AF and BK (AF - BK) and that of AF and GR (AF - GR) were increased with increase in cooking times, but the differences in moisture content between AF and DF (AF - DF), BK and DF (BK - DF), BK and GR (BK - GR) and DF and GR (DF – GR) were neither increased nor decreased 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 between 170 and 180℃ (170 – 180℃) and that of 170 and 190 ℃ (170 - 190℃) were neither increased nor decreased with increase cooking times. Similarly, the differences between 180 and 190 ºC (180 - 190ºC) 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 products from air fried (AF) at 190ºC and 16 min had the least moisture content (40.55 %), while the products obtained by baking at 170ºC for 4 min had the highest moisture content (65.94 %). The moisture coefficient of determination $R^2$ was 99.5 %. This value was very high, indicating that treatment variables and their interactions affected the observed changes in moisture content.

### 3.1.2 Changes in Protein Content

The results in protein content of chicken breast meat cooked with different methods each at170, 180 and 190ºC for 0, 4, 8, 12 and 16 min are shown in Table 2. Cooking reduced the protein content of chicken breast meat to an overall mean of 82.98 %. The protein content of raw sample was 89.17 %. This finding was higher than an earlier reported value of 89 % by Elgasim and Alkanhal [17]. The reduction in protein content of chicken breast meat treated with different cooking methods could be attributed to denaturation of sarcoplasmic proteins. Chicken has been reported to contain significant quantity of myoglobin (a major source of sarcoplasmic protein) in muscle fibre and it denatures at 62 ºC in beef.

Cooking methods significantly ($p < 0.05$) affected protein content. It was observed in Table 2 that samples cooked by air frying (AF) had an average protein content of 84.76 %, those cooked by baking (BK) had 83.63 % and deep fat frying (DF) had 79.15 %, while grilling (GR) had mean protein content of 84.39 %. The differences in protein content due to cooking methods were significant ($p < 0.05$) and samples cooked by AF had significantly ($p <0.05$) higher protein content than BK and DF cooked samples. The lower protein content of DF compared to others could be attributed to thermal denaturation of proteins.

Cooking temperature significantly ($p < 0.05$) affected protein content of cooked chicken breast meat. Table 2 showed that cooking at 170 ºC gave average protein content of 83.77 %, at 180 ºC, average protein content was 82.99 % and at 190ºC, average protein content was 82.11 %. The differences in protein content caused by cooking temperatures were significant ($p< 0.05$). Thus, protein content significantly ($p < 0.05$) reduced with increase in cooking temperature. These differences in protein content of the cooking temperatures were statistically significant ($p < 0.05$). This result agrees with reported findings of Menezes [18] who stated that higher cooking temperatures denature proteins. The reduction of protein content with increasing temperature could be attributed to increased protein denaturation and loss of moisture of cooked sample. The interaction between cooking methods and temperatures was not significant ($p > 0.05$), suggesting that the differences in protein content caused by the cooking methods were similar at each cooking temperature. It could be deduced from Table 2 that the differences in protein content between AF and DF (AF – DF) samples increased with increase in cooking temperatures. On the other hand, the differences in protein content between AF and BK (AF –BK) or between AF and GR (AF – GR) increased with increase in cooking temperatures, while the differences in protein content between BK and DF (BK – DF), BK and GR (BK –GR) as well as DF and GR (DF – GR) were similar, respectively with increase in cooking temperatures.

From this interaction, it is deduced that DF method resulted to least protein content at each cooking temperature compared to other cooking methods, with greater reduction of protein content in DF cooked sample at 190ºC cooking temperature. This may suggest that, more protein denaturation and releases of bound water and increased browning colouration at higher temperatures. Although products continued to reduce in protein content as temperature of cooking increased, the air fried (AF) products had the highest protein content at each cooking temperature, suggesting that there was less fat drip loss and release of bound water at each temperature compared with other cooking methods.

The results in Table 2 showed that cooking time affected protein content. The protein content at 4 min averaged 83.57 %, protein content at 8 min averaged 81.83 %, protein content at 12 min averaged 80.76 % and protein content at 16 min averaged 79.45 %. Thus protein content significantly ($p < 0.05$) reduced as cooking time increased. The differences in protein contents with duration of cooking could be attributed to losses by dripping or leaching. Similarly, Sharma and Sharma [2] and Alugwu [19] have reported that heat application results in destruction of some amino acids, browning of products and reduction of protein content with increase cooking time. The interaction between the cooking methods and cooking times was found to be significant ($p < 0.05$). This suggests that the protein content due to the cooking methods were different at different cooking times. The significant interaction ($p < 0.05$) showed that the differences in protein content between AF and BK (AF - BK) and that of AF and DF (AF - DF) were increased with increase in cooking times, but the differences in protein content between AF and GR (AF - GR), BK and DF (BK - DF), BK and GR (BK - GR) and DF and GR (DF – GR) were neither increased nor decreased with increase in cooking times. The results showed that the interaction between cooking temperatures and cooking times was significant ($p < 0.05$). This suggests that the differences in protein content between 170 and 180ºC (170 -180ºC) or between 170 and 190ºC (170 – 190ºC) or between 180 and 190ºC (180 -190 ºC) were neither increased nor decreased with increase in cooking times. However, the overall interaction (Method x Temperature x Time) was not significant ($p > 0.05$).The protein coefficient of determination $R^2$ was 98.3 %. This value was very high indicating that treatment variables and their interactions affected the observed decreased protein content.

#### 3.1.3 Changes in fat content

The changes in fat content of chicken breast meat cooked with different methods each at170, 180 and 190ºC for 0, 4, 8, 12 and 16 min are shown in Table 3. The results in Table 3 showed that cooking increased the fat content of chicken breast meat. On the average, fat content increased to an overall mean of 7.78 %. 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. [20] and Hussain et al. [21].

**Table 1. Moisture content (%) of chicken meat at different cooking method, temperature and time**

| Cooking Method | Cooking Temp.℃ | Cooking time (min) 0 | 4 | 8 | 12 | 16 | Mean CM |
|---|---|---|---|---|---|---|---|
| AF | 170 | 75.14 ± 0.04 | 63.98±1.26 | 62.54 ± 0.86 | 48.12 ± 0.67 | 46.21 ± 1.47 | |
| | 180 | 75.14 ± 0.04 | 63.72 ± 1.06. | 54.59 ± 1.01 | 46.23 ± 1.57 | 41.95 ± 1.32 | |
| | 190 | 75.14 ± 0.04 | 60.90 ± 1.41 | 53.30 ± 0.73 | 43.18 ± 1.34 | 40.55 ± 0.18 | |
| Mean | | 75.14 ± 0.03 | 62.87 ± 1.81 | 56.81 ±4.61 | 45.84 ±2.53 | 42.90 ±2.78 | 56.71[c] ±12.19 |
| BK | 170 | 75.14 ± 0.04 | 65.94 ± 1.39 | 60.90 ± 0.55 | 59.92 ± 1.37 | 56.13 ±0.40 | |
| | 180 | 75.14 ± 0.04 | 62.38 ± 0.71 | 57.98 ± 0.62 | 55.55 ± 1.33 | 51.68 ±1.48 | |
| | 190 | 75.14 ± 0.04 | 61.62 ± 0.84 | 57.28 ± 0.65 | 52.21 ± 0.37 | 49.51 ± 0.75 | |
| Mean | | 75.14 ± 0.03 | 63.31 ±2.30 | 58.72 ±1.89 | 55.89 ±3.57 | 52.44 ±3.11 | 61.10 [a]±8.33 |
| DF | 170 | 75.14 ± 0.04 | 58.18 ± 1.46 | 57.91 ± 1.33 | 51.98 ± 0.38 | 45.64 ± 1.12 | |
| | 180 | 75.14 ± 0.04 | 55.58 ± 1.39 | 53.67 ± 0.99 | 50.46 ± 0.65 | 43.42 ± 0.51 | |
| | 190 | 75.14 ± 0.04 | 55.26 ± 0.90 | 51.59 ±0.94 | 46.74 ±1.08 | 41.47 ±0.75 | |
| Mean | | 75.14 ± 0.03 | 56.34 ±1.74 | 54.39 ±3.01 | 49.73 ±2.48 | 43.51±1.97 | 55.82 [d]±10.98 |
| GR | 170 | 75.14 ± 0.04 | 62.70 ± 1.30 | 59.02 ± 1.49 | 57.69 ± 1.20 | 54.17 ± 0.81 | |
| | 180 | 75.14 ± 0.04 | 62.07± 0.92 | 55.22 ± 1.17 | 51.41 ± 1.41 | 50.12 ± 1.34 | |
| | 190 | 75.14 ± 0.04 | 61.55 ± 0.55 | 53.18 ± 1.03 | 50.60 ± 1.20 | 47.98 ± 1.34 | |
| Mean | | 75.14 ± 0.03 | 62.11 ± 0.91 | 55.81±2,82 | 53.02±3.81 | 50.76±2.96 | 59.37[b]± 9.21 |
| | Grand mean | 75.14[a]± 0.03 | 61.16[b]± 3.31 | 56.43 [c]±3.42 | 51.12[d]±4.83 | 47.40[e]±5.03 | 58.25± 10.79 |

*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; BK: Baking; DF: Deep Fat Frying; GR Grilling*

**Table 2. Protein content (%) of chicken meat at different cooking method, temperature and time**

| Method | Cooking Temp. ℃ | Cooking time (min) 0 | 4 | 8 | 12 | 16 | CM mean - |
|---|---|---|---|---|---|---|---|
| AF | 170 | 89.17 ±1.07 | 85.73 ± 0.88 | 84.27 ± 1.22 | 83.56 ± 1.03 | 82.95 ± 1.29 | |
| | 180 | 89.17 ± 1.07 | 85.61 ± 0.56 | 83.83 ± 0.30 | 83.18 ± 0.10 | 82.20 ± 0.10 | |
| | 190 | 89.17 ± 1.07 | 85.15 ± 0.80 | 83.50± 0.04 | 82.05 ± 0.25 | 81.90 ± 0.11 | |
| Mean | | 89.17 ± 0.83 | 85.49 ±0.65 | 83.87 ±0.66 | 82.93 ± 0.85 | 82.35 ±1.14 | 84.76[a] ± 2.61 |
| BK | 170 | 89. 17 ± 1.07 | 85.43 ± 0.91 | 84.38± 0.59 | 81.92 ± 0.07 | 80.90 ± 0.70 | |
| | 180 | 89.17 ± 1.07 | 84.44 ± 0.45 | 82.91 ± 0.62 | 81.08 ± 0.27 | 80.41 ± 0.16 | |
| | 190 | 89.17 ± 1.07 | 84.17 ± 0.01 | 81.66 ± 0.98 | 80.52 ± 0.16 | 77.46 ± 0.70 | |
| Mean | | 89. 17 ± 0.83 | 84.68 ± 0.75 | 82.98 ± 1.35 | 81.17 ± 0.65 | 79.59 ± 1.72 | 83.52[b] ± 3.59 |
| DF | 170 | 89. 17 ± 1.07 | 81.59 ± 0.30 | 77.37 ± 1.05 | 76.32 ± 0.08 | 75.84 ± 0.44 | |
| | 180 | 89.17 ± 1.07 | 79.12 ± 0.93 | 77.08 ± 0.86 | 76. 22 ± 0.91 | 74.06 ± 0.25 | |
| | 190 | 89.17 ± 1.07 | 78.22 ± 0.55 | 75.45 ± 0.27 | 75.07 ± 0.27 | 73.44 ± 0.96 | |
| Mean | | 89.17 ± 0.83 | 79..64 ± 1.64 | 76.63 ± 1.11 | 75.86 ± 0.75 | 74.45 ± 1.22 | 79.15[c] ± 1.49 |
| GR | 170 | 89.17 ± 1.07 | 85.77 ± 0.93 | 85.36 ± 0.84 | 84.17 ± 0.22 | 83.20 ± 0.48 | |
| | 180 | 89.17 ± 1.07 | 84.76 ± 0.28 | 83.14 ± 0.10 | 82.82 ± 0.11 | 82.31 ± 0.13 | |
| | 190 | 89.17± 1.07 | 83.04 ± 1.40 | 82.91 ± 0.30 | 82.21± 0.54 | 78.69 ± 0.99 | |
| Mean | | 89.17± 0.83 | 84.48± 1.50 | 83.85± 1.24 | 83.06± 0.94 | 81.40 ± 1.29 | 84.39[a]± 2.96 |
| | Grand mean | 89.17 [a] ±0.78 | 83.57[b]± 2.61 | 81.83 [c] ±3.26 | 80.76 [d] ±3.08 | 79.45[e] ± 3.47 | 82.98±4.38 |

*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; BK: Baking; DF: Deep Fat Frying; GR: Grilling*

Cooking methods significantly ($p < 0.05$) affected fat content. It was observed in Table 3 that samples cooked by air frying (AF) had an average fat content of 6.74 %, those cooked by baking (BK) had 6.62 %, and deep fat frying (DF) had 11.88 %, while grilling (GR) had mean fat content of 5.87 %. The differences in fat content due to cooking methods were significant ($p < 0.05$) and samples cooked by GR had significantly ($p <0.05$) lower fat content than others. The lower fat content of GR cooked samples compared to others could be attributed to losses by drip off as the fat melts from the samples. There were no significant differences ($p > 0.05$) in the fat content between BK and AF cooked samples. Similar results have been reported by Gokoglu et al. [22] and Salawu et al. [23], respectively. The DF cooked samples had significantly ($p < 0. 05$) the highest fat content at 170 ºC (10.97 %), 180 ºC (11.96 %) and 190 ºC (12.70 %). These higher fat contents were due to high fat level of 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, AF and GR, BK and DF, BK and GR with cooking time. It was observed in Table 3 that cooking at 170 ºC gave average fat content of 7.00 %, at 180ºC average fat content was 7.89 % and at 190 ºC, average fat content was 8.43 %. 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 ºC resulted to significantly ($p < 0.05$) lower fat content than cooking at 180ºC and 190ºC. The increased of fat content with increase 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 3 showed that cooking time affected fat content. The fat content at 4 min averaged 7.02 %, fat content at 8 min averaged 8.12 %, fat content at 12 min averaged 9.37 % and fat content at 16 min averaged 10.12 %. Thus fat content significantly ($p < 0.05$) increased as cooking time increased. The differences are attributed to contact time 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 BK (AF - BK) and that of AF and GR (AF - GR) were nether increased nor decreased and similar with increase in cooking times, but the differences in fat content between AF and DF (AF - DF), BK and DF (BK - DF), BK and GR (BK - GR) and DF and GR (DF – GR) were increased, 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 ºC (170 – 180 ºC) or between 180 and 190 ºC (180 – 190 ºC) were neither increased nor decreased with increase in cooking times. On the other hand, the differences in fat content between 170 and 190 ºC (170 – 190 ºC) were increased with increase in cooking times. However, the overall interaction (Method x Temperature x Time) was not significant. The fat coefficient of determination $R^2$ was 97.1 %.

This value was very high, indicating that treatment variables and their interactions affected the observed increased fat content.

#### 3.1.4 Changes in ash content

The changes in ash content of chicken breast meat cooked with different methods each at170, 180 and 190℃ for 0, 4, 8, 12 and 16 min are shown in Table 4. The results in Table 4 showed that cooking increased the ash content of chicken breast meat from 1.95 % to an overall mean of 2.39 %. The increased in ash content of chicken breast meat treated with different cooking methods could be attributed to moisture content losses by cooking and associated increases in dry matter contents. This finding agrees with similar result reported by Rosa et al. [15], Achir et al. [20] and Hussain et al. [21] on chicken breast meat samples. The levels of ash content in chicken meat were indications of presence of mineral elements which are important substances in human health.

Cooking methods significantly ($p < 0.05$) affected ash content. It was observed in Table 4 that air frying (AF) samples had an average ash content of 2.39 %, while samples cooked by baking (BK) had 2.38 %, deep fat frying (DF) had 2.46 % and grilling (GR) had of 2.34 %. The differences in ash content due to cooking methods were significant ($p < 0.05$). Samples cooked by DF had significantly ($p < 0.05$) the highest ash content than others. The highest ash content of

DF cooked samples compared to others could be attributed to uptake of soluble matters and impurity by cooked meat from the cooking oil. There were no significant differences ($p > 0.05$) in the ash content between AF and BK cooked samples.

Cooking temperature significantly ($p < 0.05$) affected ash content of cooked chicken breast meat. It was observed in Table 4 that cooking at 170 ºC gave average ash content of 2.15 %, at 180 ºC average ash content was 2.46 % and at 190 ºC, average ash content was 2.57 %. Thus, ash content significantly ($p < 0.05$) increased with increase in cooking temperature. This result is in agreement with earlier studies of Oparaku and Mgbenka [24] which stated that the ash content of fresh Clarius gariepmus increased from 1.79 % fresh to 4.85 % (solar dried) and 3.08 % (electric oven dried). The increases of ash content with increasing temperature could be attributed to dehydration effects of heat and concentration of dry matters. The interaction between cooking methods and temperatures was significant ($p < 0.05$), suggesting that the differences in ash content caused by the cooking methods were different at different cooking temperatures. It could be deduced from Table 4 that the differences in ash content between AF and DF (AF – DF) samples decreased with increase in cooking temperatures. On the other hand, the differences in ash content between AF and BK (AF –BK) or between AF and GR (AF – GR) were neither increased nor decreased with increase in cooking temperatures, while the differences in ash content between BK and DF (BK – DF), BK and GR (BK –GR) as well as DF and GR (DF – GR) respectively neither increased nor decreased, decreased and decreased each with increase in cooking temperatures. From this interaction, it is deduced that DF cooked samples had the highest ash content at each cooking temperature compared to other cooking methods. This may suggest that DF cooked samples absorbed soluble matters and impurity from the cooking oil and it resulted to their ash content increase. The results in Table 4 showed that cooking time affected ash content. The ash content at 4 min averaged 2.31 %, ash content at 8 min averaged 2.48 %, ash content at 12 min averaged 2.55 % and ash content at 16 min averaged 2.67 %.

Thus ash 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 not significant ($p > 0.05$). The results showed that the interaction between cooking temperatures and cooking times were significant ($p < 0.05$). This suggests that the differences in ash content between 170 and 180ºC (170 – 180ºC), between 170 and 190ºC (170 – 190ºC) and between 180 and 190ºC (180 – 190ºC) were different at each cooking time. However, the overall interaction (Method x Temperature x Time) was significant. This significant ($p < 0.05$) of overall interaction confirmed why the products air fried (AF) at 170ºC and 4 min had the least ash content of 2.01 %, while the products obtained by deep fat frying at 190ºC for 16 min had the highest ash content of 2.91 %. The ash coefficient of determination $R^2$ was 97.1 %. This value was very high, indicating that treatment variables and their interactions affected the observed changes ash content.

### 3.1.5 Changes in carbohydrate content

The results of the changes in carbohydrate content of chicken breast meat cooked with different methods each at170, 180 and 190 ºC for 0, 4, 8, 12 and 16 min are shown in Table 5. The results in Table 5 showed that cooking increased the carbohydrate content of chicken breast meat to an overall mean of 6.95 %. The increases in carbohydrate content of chicken breast meat treated with different cooking methods could be attributed to conversion of stored starch to dextrin and subsequently coated with browning colour. Cooking methods significantly ($p < 0.05$) affected carbohydrate content. It was observed in Table 5 that samples cooked by air frying (AF) had an average carbohydrate content of 6.11 %, those cooked by baking (BK) had 7.45 % and deep fat frying (DF) had 6.84 %, while grilling (GR) had mean carbohydrate content of 7.41 %. The differences in carbohydrate content due to cooking methods were significant ($p < 0.05$) and BK cooked samples had significantly ($p <0.05$) higher carbohydrate content than AF cooked samples. The lower carbohydrate content of AF cooked samples compared to other cooking methods could be attributed to higher cooking temperatures which converted its samples stored starch to brown coatings as reported by Davidson [25].

Cooking temperature had no significant ($p > 0.05$) effect on carbohydrate content of cooked chicken breast meat. It was observed in Table 5 that cooking at 170ºC gave average carbohydrate content of 7.02 %, at 180 ºC average carbohydrate content was 6.92 % and at 190 ºC, average carbohydrate content was 6.92 %. The differences in carbohydrate content caused by cooking temperatures were not significant ($p > 0.05$). The interaction between cooking methods and temperatures was not significant ($p > 0.05$). The results in Table 5 showed that cooking time affected carbohydrate content of cooked chicken breast meat. The carbohydrate content at 4 min averaged 7.50 %, carbohydrate content at 8 min averaged 7.55 %, carbohydrate content at 12 min averaged 7.33 % and carbohydrate content at 16 min averaged 7.76 %. Thus carbohydrate content significantly ($p < 0.05$) increased as cooking time increased except in 12 min cooked samples. The differences are attributed to contact time of the products in the cooking medium. The interaction between the cooking methods and cooking times was not significant ($p > 0.05$). The results showed that the interaction between cooking temperatures and cooking times was significant ($p < 0.05$). The significant interaction ($p < 0.05$) showed that the differences in carbohydrate content of chicken breast meat between 170 and 180ºC (170 – 180ºC) or between 170 and 190ºC (170 – 190ºC or between 180 and 190 ºC (180 – 190ºC) were neither increased or decreased with increase in cooking time. However, the results of the interaction between (Cooking method x Temperature x Time) were not found to be significant ($p > 0.05$). The coefficient of determination $R^2$ was 75.10 %. This value was very high, indicating that treatment variables and their interactions affected the observed changes in carbohydrate content.

## 3.2 Changes in Textural Properties of Chicken Breast Meat

### 3.2.1 Changes in cohesiveness

The results of the changes in cohesiveness content of chicken breast meat cooked at different methods each at 170, 180 and 190 °C for 0, 4, 8, 12 and 16 min are shown in Table 6. The results showed that cooking increased the cohesiveness of chicken to an overall mean of 0.52. Cooking methods significantly ($p < 0.05$) affected cohesiveness content of chicken breast meat. The results in Table 6 showed that samples cooked by air frying (AF) had an average cohesiveness content of 0.55, while samples cooked by baking (BK) had 0.51, deep fat frying (DF) had 0.48 and grilling (GR) had mean cohesiveness content of 0.54. The differences in cohesiveness content due to cooking methods were significant ($p < 0.05$) and AF cooked samples had significantly ($p < 0.05$) higher cohesiveness content compared with BK and DF cooking methods. The increases in cohesiveness content due to cooking could be attributed to higher moisture losses from the product upsetting the viscoelastic behaviour of the products. This similar finding was reported by Pandey et al*.* [26] and Nithyalakshmi and Preetha [27]. Cooking temperature significantly ($p < 0.05$) affected cohesiveness content of cooked chicken breast meat. Cooking at 170 °C gave average cohesiveness content of 0.50, at 180 °C average cohesiveness content was 0.52 and at 190 °C, average cohesiveness content was 0.55. Thus, cohesiveness content significantly ($p < 0.05$) increased with increase in cooking temperature. The differences in cohesiveness content caused by cooking temperatures were significant ($p< 0.05$). Cooking at 190 °C resulted to significantly ($p < 0.05$) higher cohesiveness content than cooking at 170 °C and 180 °C. The increased cohesiveness of cooked samples with increase temperature could be attributed to fluid losses and disjointing of the samples. The interaction between cooking methods and temperatures was not significantly different ($p > 0.05$), suggesting that the differences in cohesiveness content caused by the cooking methods were similar at each cooking temperature. The results in Table 6 showed that cooking times affected cohesiveness content. The cohesiveness content at 4 min averaged 0.48, at 8 min averaged 0.53, at 12 min averaged 0.57 and at 16 min averaged 0.63. Thus cohesiveness content significantly ($p < 0.05$) increased as cooking time increase. The differences are attributed to contact time of the products in the cooking medium The interaction between the cooking methods and cooking times was found to be significant ($p < 0.05$), suggesting that the cohesiveness content due to the cooking methods were different at different cooking times. The significant interaction ($p < 0.05$) showed that the differences in cohesiveness content between BK and GR (BK - GR) were increased with increase in cooking times, but differences in between AF and DF (AF - DF) were decreased with increase in cooking times. On the other hand, the differences in cohesiveness content between AF and BK (AF – BK) or AF and GR (AF - GR) or BK and DF (BK - DF) or DF and GR (DF - GR) were neither increased nor decreased with increase in cooking times. The results showed that the interaction between cooking temperatures and cooking times was not significant ($p > 0.05$), suggesting that the differences in cohesiveness content caused by the cooking temperatures were similar at each cooking times. However, the overall interaction (Method x Temperature x Time) was also not significant. The cohesiveness coefficient of determination $R^2$ was 94.20 %. This value was very high, indicating that treatment variables and their interactions affected the observed increases in cohesiveness content.

**Table 3. Fat content (%) of chicken meat at different cooking method, temperature and time**

| Cooking Method | Cooking Temp. ℃ | Cooking time (min) 0 | 4 | 8 | 12 | 16 | Mean |
|---|---|---|---|---|---|---|---|
| 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 |
| BK | 170 | 4.26 ±0.78 | 4.84 ± 0.81 | 5.35 ± 0.41 | 7.01 ± 1.00 | 7.40 ± 0.22 | |
| | 180 | 4.26 ±0.78 | 5.38 ± 1.13 | 6.47 ± 1.05 | 7.92 ± 1.29 | 9.64 ± 1.00 | |
| | 190 | 4.26 ±0.78 | 6.18 ± 0.36 | 7.38 ± 0.83 | 9.14 ± 1.00 | 9.88 ± 0.28 | |
| Mean | | 4.26 ±0.61 | 5.46 ± 0.88 | 6.40 ± 1.10 | 8.02 ± 1.28 | 8.97 ± 1.31 | 6.62 $^b$ ± 1.99 |
| 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 |
| GR | 170 | 4.26 ±0.78 | 4.65 ± 0.12 | 5.29 ± 0.11 | 6.35± 1.44 | 6.38 ± 0.46 | |
| | 180 | 4.26 ±0.78 | 5.03 ± 0.11 | 6.48 0.54 | 6.94 ±0.28 | 7.12 ±0.88 | |
| | 190 | 4.26 ±0.78 | 5.52 ± 0.45 | 6.22 ± 0.81 | 7.57 ± 0.75 | 7.75 ± 1.14 | |
| Mean | | 4.26 ±0.61 | 5.07 ±0.45 | 5.98 ± 0.70 | 6.93 ± 0.90 | 7.09 ± 0.92 | 5.87 $^c$± 1.30 |
| | Grand mean | 4.26$^e$± 0.57 | 7.02$^d$± 2.71 | 8.12 $^c$± 3.19 | 9.36 $^b$± 3.38 | 10.12 $^a$±3.65 | 7.78±2.29 |

*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; BK: Baking; DF: Deep Fat Frying; GR: Grilling*

**Table 4. Ash content (%) of chicken meat at different cooking method, temperature and time**

| Cooking Method | Cooking temp ℃ | Cooking time (min) 0 | 4 | 8 | 12 | 16 | Mean cooking temp ℃ | Mean cooking Method |
|---|---|---|---|---|---|---|---|---|
| AF | 170 | 1.95±0.10 | 2.01±0.12 | 2.09±0.10 | 2.19±0.10 | 2.34±0.04 | 2.13 | |
| | 180 | 1.95±0.10 | 2.33±0.08 | 2.53±0.02 | 2.60±0.04 | 2.76±0.01 | 2.43 | |
| | 190 | 1.95±0.10 | 2.64±0.02 | 2.72±0.02 | 2.81±0.02 | 2.90±0.01 | 2.60 | |
| Mean | | 1.95 ±0.07 | 2.33 ± 0.29 | 2.45 ± 0.29 | 2.53 ± 0.21 | 2.70 ± 0.21 | 2.39 | 2.39$^b$± 0.24 |
| BK | 170 | 1.95±0.10 | 2.05 ±0.10 | 2.16 ±0.16 | 2.19 ± 0.10 | 2.58 ±0.02 | 2.19 | |
| | 180 | 1.95 ±0.10 | 2.13 ± 0.11 | 2.58 ± 0.05 | 2.63 ± 0.03 | 2.70 ± 0.10 | 2.40 | |
| | 190 | 1.95 ±0.10 | 2.56 ± 0.02 | 2.66 ± 0.01 | 2.77 ± 0.01 | 2.85± 0.01 | 2.56 | |
| Mean | | 1.95 ±0.07 | 2.24 ± 0.25 | 2.47 ± 0.25 | 2.53 ± 0.27 | 2.71 ± 0.12 | 2.38 | 2.38$^b$ ±0.21 |
| DF | 170 | 1.95 ±0.10 | 2.05 ± 0.08 | 2.37 ± 0.10 | 2.43 ± 0.01 | 2.57 ± 0.01 | 2.27 | |
| | 180 | 1.95 ±0.10 | 2.57 ± 0.27 | 2.60 ± 0.05 | 2.75 ± 0.02 | 2.78 ± 0.01 | 2.53 | |
| | 190 | 1.95 ±0.10 | 2.52 ± 0.07 | 2.78 ± 0.00 | 2.79 ± 0.01 | 2.91±0.02 | 2.59 | |
| Mean | | 1.95 ±0.07 | 2.38 ± 0.29 | 2.58 ± 0.14 | 2.65 ± 0.19 | 2.75 ± 0.15 | 2.46 | 2.46$^a$ ±0.17 |
| GR | 170 | 1.95 ±0.10 | 1.97 ±0.00 | 1.98 ±0.16 | 2.05 ± 0.07 | 2.06 ±0.08 | 2.00 | |
| | 180 | 1.95 ±0.10 | 2.43 ± 0.12 | 2.56 ±0.00 | 2.67± 0.06 | 2.72 ± 0.05 | 2.47 | |
| | 190 | 1.95 ±0.10 | 2.49 ±0.07 | 2.72 ± 0.11 | 2.75 ± 0.00 | 2.81 ± 0.04 | 2.54 | |
| Mean | | 1.95 ±0.07 | 2.30 ± 0.26 | 2.42 ± 0.35 | 2.50 ± o.36 | 2.53 ± 0.37 | 2.34 | 2.34$^c$±0.29 |
| | Grand mean | 1.95 $^e$ ±0.07 | 2.31$^d$± 0.27 | 2..48$^c$± 0.28 | 2.55 $^b$± 0.27 | 2.67 ± 0.24 | | 2.39±0.28 |

*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; BK: Baking; DF: Deep Fat Frying; GR: Grilling*

**Table 5. Carbohydrate content (%) of chicken meat at different cooking method, temperature and time**

| Cooking Method | Cooking temp ℃ | Cooking time (min) 0 | 4 | 8 | 12 | 16 | Mean cooking temp ℃ | Method |
|---|---|---|---|---|---|---|---|---|
| AF | 170 | 4.63 ±1.93 | 6.38 ±2.02 | 7.52 ±0.08 | 7.89 ±0.10 | 7.85 ±2.45 | 6.85 | |
| | 180 | 4.63 ±1.93 | 5.84±1.18 | 6.78±1.65 | 6.33 ±1.15 | 5.73 ±0.62 | 5.86 | |
| | 190 | 4.63 ±1.93 | 5.63±1.56 | 6.28 ±0.70 | 5.98±0.84 | 5.60 ±1.17 | 5.62 | |
| Mean | | 4.63±1.52 | 5.95 ±1.56 | 6.86 ±0.98 | 6.73 ±1.11 | 6.39 ±1.68 | | $6.11^{b}$±1.53 |
| BK | 170 | 4.63 ±1.93 | 7.69 ±0.19 | 7.33 ± 0.76 | 8.88±1.06 | 9.13±0.472.75 | 7.53 | |
| | 180 | 4.63 ±1.93 | 8.05 ± 0.57 | 7.67 ± 0.91 | 8.38 ±1.58 | 7.26 ± 0.86 | 7.20 | |
| | 190 | 4.63 ±1.93 | 6.85 ±0.00 | 9.21±2.08 | 7.58 ±1.15 | 9.82 ±0.39 | 7.62 | |
| Mean | | 4.63±1.52 | 7.53 ± 0.61 | 8.07 ±1.40 | 8.28 ±1.15 | 8.74 ± 1.27 | | $7.45^{a}$± 1.88 |
| DF | 170 | 4.63 ±1.93 | 5.73 ±0.49 | 8.21 ±0.90 | 7.62 ±1.85 | 6.88 ±1.16 | 6.61 | |
| | 180 | 4.63 ±1.93 | 12.95 ±0.07 | 6.57 ±1.41 | 6.41±1.08 | 6.83±1.57 | 7.48 | |
| | 190 | 4.63 ±1.93 | 6.34 ±1.09 | 7.79 ±0.30 | 6.33 ±0.25 | 7.12 ±1.69 | 6.44 | |
| Mean | | 4.63±1.52 | 8.34 ±1.62 | 7.52±1.08 | 6.78 ±1.16 | 6.94 ±1.16 | | $6.84^{a}$±2.21 |
| GR | 170 | 4.63 ±1.93 | 7.62±0.82 | 7.37 ±1.10 | 7.45 ±1.14 | 8.37 ±0.87 | 7.09 | |
| | 180 | 4.63 ±1.93 | 7.78 ±0.51 | 7.86 ±0.44 | 7.57 ±0.46 | 7.86 ±0.69 | 7.14 | |
| | 190 | 4.63 ±1.93 | 9.08 ±1.02 | 8.03 ±0.40 | 7.52±0.20 | 10.73 ±1.75 | 8.00 | |
| Mean | | 4.63±1.52 | 8.16 ±0.95 | 7.75 ±0.64 | 7.52±0.56 | 8.98 ±1.91 | | $7.41^{a}$± 1.89 |
| | Grand mean | $4.63^{b}$ ±1.41 | $7.49^{a}$±2.14 | $7.55^{a}$±1.09 | $7.33^{a}$ ±1.16 | $7.76^{a}$ ±1.83 | | 6.95 ±1.95 |

*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; BK: Baking; DF: Deep Fat Frying; GR: Grilling*

**Table 6. Cohesiveness of chicken breast at different cooking method, temperature and time**

| Cooking Method | Cooking temp. ℃ | Cooking time (min) 0 | 4 | 8 | 12 | 16 | Mean -CM |
|---|---|---|---|---|---|---|---|
| AF | 170 | 0.40 ± 0.04 | 0.51 ± 0.06 | 0.56 ± 0.01 | 0.60 ± 0.03 | 0.64 ± 0.02 | |
| | 180 | 0.40 ± 0.04 | 0.51± 0.06 | 0.56 ± 0.01 | 0.61± 0.04 | 0.66 ± 0.04 | |
| | 190 | 0.40 ± 0.04 | 0.59 ± 0.01 | 0.60 ± 0.01 | 0.62 ± 0.01 | 0.68 ± 0.06 | |
| Mean | | 0.40 ± 0.04 | 0.53 ± 0.05 | 0.57 ± 0.02 | 0.61 ± 0.02 | 0.66 ± 0.04 | $0.55^{a}$ ± 0.02 |
| BK | 170 | 0.40 ± 0.04 | 0.46 ± 0.00 | 0.51 ± 0.01 | 0.53 ± 0.01 | 0.55 ± 0.02 | |
| | 180 | 0.40 ± 0.04 | 0.47 ± 0.00 | 0.54 ± 0.00 | 0.55 ± 0.00 | 0.60 ± 0.01 | |
| | 190 | 0.40 ± 0.04 | 0.51 ± 0.01 | 0.57 ± 0.01 | 0.58 ± 0.00 | 0.66 ± 0.04 | |
| Mean | | 0.40 ± 0.04 | 0.48 ± 0.02 | 0.54 ± 0.03 | 0.55 ± 0.02 | 0.60 ± 0.06 | $0.51^{b}$ ± 0.03 |
| DF | 170 | 0.40 ± 0.04 | 0.41 ± 0.01 | 0.43 ± 0.04 | 0.49 ± 0.01 | 0.55 ±0.01 | |
| | 180 | 0.40 ± 0.04 | 0.42 ± 0.01 | 0.47 ± 0.01 | 0.52 ± 0.03 | 0.62 ± 0.01 | |
| | 190 | 0.40 ± 0.04 | 0.44 ± 0.02 | 0.48± 0.01 | 0.54 ± 0.01 | 0.63 ± 0.01 | |
| Mean | | 0.40 ± 0.04 | 0.42 ± 0.02 | 0.46 ± 0.03 | 0.52 ± 0.03 | 0.60 ± 0.07 | $0.48^{c}$± 0.02 |
| GR | 170 | 0.40 ± 0.04 | 0.46 ± 0.01 | 0.53 ± 0.02 | 0.57 ± 0.00 | 0.64 ± 0.02 | |
| | 180 | 0.40 ± 0.04 | 0.49 ± 0.00 | 0.56 ± 0.01 | 0.59 ± 0.01 | 0.66 0.01 | |
| | 190 | 0.40 ± 0.04 | 0.53 ± 0.02 | 0.58 ± 0.01 | 0.63 ± 0.06 | 0.70 ± 0.11 | |
| Mean | | 0.40 ± 0.04 | 0.49 ± 0.03 | 0.55 ± 0.02 | 0.60 ± 0.04 | 0.66 ± 0.06 | $0.54^{a}$ ± 0.02 |
| | Grand Mean | $0.40^{e}$ ± 0.04 | $0.48^{d}$±0.05 | $0.53^{c}$± 0.05 | $0.57^{b}$±0.05 | $0.63^{a}$±0.05 | 0.52 ± 0.09 |

*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; BK: Baking; DF: Deep Fat Frying; GR: Grilling*

### 3.2.2 Changes in chewiness

The results of the changes in chewiness value of chicken breast meat cooked by different methods each at 170, 180 and 190 °C for 0, 4, 8, 12 and 16 min are shown in Table 7. It was observed in Table 7 that cooking increased chewiness value by softening the collagen and connective tissues of meat cuts. The chewiness value of chicken breast meat increased from 3.63 to 6.05kg. Cooking methods significantly ($p < 0.05$) affected chewiness of chicken breast meat. The results in Table 7 showed that samples cooked by air frying (AF) had an average chewiness value of 5.96 kg, while samples cooked by baking (BK) had 5.21 kg, deep fat frying (DF) had 6.99 kg and grilling (GR) had mean chewiness value of 6.04 kg. The results in Table 7 showed that chewiness of muscle foods increased with cooking. This result agrees with reported findings by Nithyalakshmi and Preetha [27] in cooked Emu meat. Chewiness of chicken breast is a product of hardness, cohesiveness and springiness. The differences in chewiness content due to cooking methods were significant ($p < 0.05$) and DF cooked samples had significantly ($P < 0.05$) the highest mean chewiness value of 6.99 kg compared to other cooking methods. The increased chewiness of cooked samples could be attributed to heat softening effects and solubilisation of meat connective tissues and conversion of collagen to gelatin.

Cooking temperature significantly ($p < 0.05$) affected chewiness value of cooked chicken breast meat. Cooking at 170 °C gave average chewiness value of 5.50 kg, at 180 °C average chewiness value was 5.89 kg and at 190 °C, average chewiness value was 6.77 kg. Thus, chewiness content significantly ($p < 0.05$) increased with increase in cooking temperature. The differences in chewiness value caused by cooking temperatures were significant ($p< 0.05$). Cooking at 190 °C resulted to significantly ($p < 0.05$) higher chewiness value than cooking at 170 °C and 180 °C. The increased chewiness of cooked samples could be attributed to heat-induced shrinkage and solubilisation of connective tissue. This result agrees with similar findings by Pandey et al. [26] who stated that chewiness of kebabs increases with cooking temperatures and cooking time. The interaction between cooking methods and temperatures was not significant ($p > 0.05$), suggesting that the differences in chewiness value caused by the cooking methods were similar at each temperature.

**Table 7. Chewiness (kg) of chicken meat at different cooking method, temperature and time**

| Cooking | Cooking | Cooking time (min) | | | | | Mean |
|---|---|---|---|---|---|---|---|
| **Method** | **temp. °C** | **0** | **4** | **8** | **12** | **16** | **C M** |
| AF | 170 | 3.63 ± 0.67 | 3.97 ± 0.28 | 4.92 ± 0.13 | 7.32 ± 0.07 | 7.47 ± 0.37 | |
| | 180 | 3.63 ± 0.67 | 4.17 ± 1.12 | 5.77 ± 0.45 | 7.33 ± 0.05 | 8.54 ± 0.83 | |
| | 190 | 3.63 ± 0.67 | 4.35 ± 0.29 | 7.03 ± 0.77 | 8.45 ±0.93 | 9.14 ± 0.01 | |
| Mean | | 3.63 ± 0.52 | 4.16 ± 0.56 | 5.91 ± 1.03 | 7.70 ± 0.72 | 8.39 ± 0.86 | 5.96$^{b}$± 2.03 |
| BK | 170 | 3.63 ± 0.67 | 3.85 ± 0.19 | 4.15 ± 0.55 | 4.48 ± 0.57 | 6.55 ± 0.78 | |
| | 180 | 3.63 ± 0.67 | 4.08 ± 0.15 | 4.37 ± 0.90 | 4.86 ±1.11 | 6.92 ± 0.82 | |
| | 190 | 3.63 ± 0.67 | 4.37 ± 0.55 | 6.04 ± 0.67 | 7.16 ± 0.58 | 10.45 ± 0.14 | |
| Mean | | 3.63 ± 0.52 | 4.10 ± 0.36 | 4.85 ± 1.08 | 5.50 ± 1.44 | 7. 97 ± 1.99 | 5.21$^{c}$± 1.92 |
| DF | 170 | 3.63 ± 0.67 | 5.17 ± 0.38 | 6.68 ± 0.38 | 8.03 ± 1.19 | 8.90 ± 0.83 | |
| | 180 | 3.63 ± 0.67 | 6.12 ± 0.48 | 7.58 ± 0.04 | 8.39 ± 0.11 | 9.02 ± 0.14 | |
| | 190 | 3.63 ± 0.67 | 7.20 ± 0.08 | 8.17 ± 0.09 | 9.20 ± 0.13 | 9.71 ± 0.03 | |
| Mean | | 3.63 ± 0.52 | 6.16 ±0.95 | 7.48 ± 0.69 | 8.48 ± 0.70 | 9.21 ± 0.54 | 6.99$^{a}$± 2.10 |
| GR | 170 | 3.63 ± 0.67 | 4.05 ± 0.91 | 4.89 ± 0.31 | 7.05 ± 0.25 | 7.91 ± 0.19 | |
| | 180 | 3.63 ± 0.67 | 4.51 ± 0.10 | 5.71 ± 0.61 | 7.63 ± 0.81 | 8.19 ± 0.48 | |
| | 190 | 3.63 ± 0.67 | 4.72 ± 0.09 | 6.70 ± 0.66 | 8.71 ± 0.43 | 9.69 ± 0.10 | |
| Mean | | 3.63 ± 0.52 | 4.43 ± 0.51 | 5.77 ± 0.91 | 7.79 ± 0.87 | 8.60 ± 0.88 | 6.04$^{b}$± 2.06 |
| | Grand mean | 3.63$^{e}$ ± 0.48 | 4.71$^{d}$ ± 1.05 | 6.00$^{c}$ ± 1.30 | 7.37$^{b}$ ± 1.46 | 8.54$^{a}$ ± 1.21 | 6.05 ± 0.66 |

*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*
*BK baking*
*DF deep fat frying*
*GR grilling*

Table 7 showed that cooking times affected chewiness value. The chewiness value at 4 min averaged 4.71 kg, chewiness content at 8 min averaged 6.00 kg, at 12 min averaged 7.37 kg and at 16 min averaged 8.54 kg. Thus chewiness value significantly ($p < 0.05$) increased with increase in cooking time. The differences are attributed to long time exposition of the products in the cooking medium which contributes greatly to softening, solubilisation of connective tissues and conversion of collagen to gelatin. This result agrees with similar findings by Pandey et al. [26] who stated that chewiness of kebabs increase with cooking time. Moreover, heat emanating from cooking source resulted in structural changes of cooked meat due to shrinkage of intramuscular collagen, the shrinkage and denaturation of actomyosin as reported by Li et al. [28]. The interaction between the cooking methods and cooking times was found to be significant ($p < 0.05$), suggesting that the chewiness value due to the cooking methods were different at different cooking times. The significant interaction ($p < 0.05$) showed that the differences in chewiness value between DF and GR (DF - GR) were decreasing with increase in cooking times, but differences in chewiness value between AF and DF (AF - DF) were similar with increase in cooking times. On the other hand, the differences in chewiness value between AF and BK (AF - BK) or between AF and GR (AF – GR) or between BK and DF (BK - DF) or between BK and GR (BK - GR) were neither increased nor decreased with increase in cooking time. There was significant interaction ($p < 0.05$) between cooking temperatures and cooking times. The significant interaction ($p < 0.05$), suggesting that the differences in chewiness value between170 and 180 °C (170 – 180 °C) or between170 and 190 °C (170 – 190 °C) were neither increased nor decreased with increase in cooking times. Whereas, the differences in chewiness value between180 and 190 °C (180 – 190 °C) were increased with increase in cooking times. However, the overall interaction (Method x Temperature x Time) was not significant ($p > 0.05$). The coefficient of determination $R^2$ was 96.2 %. This value was very high, indicating that treatment variables and their interactions affected the observed increases in chewiness value [29,30].

## 4. CONCLUSION

Dry heat cooking methods result in moisture losses and uptake of cooking oil. Cooking temperatures and times significantly ($p < 0.05$) decreased moisture and protein contents, but increased significantly ($p < 0.05$) fat, ash, cohesiveness and chewiness. Cooking times also increased non-significantly ($p > 0.05$) carbohydrate content of cooked chicken breast meat. There were no significant differences ($p > 0.05$) in chewiness value of the samples cooked by AF and GR methods.

The centres of samples cooked by DF method were hotter than other cooking methods, while centre temperatures of samples cooked by AF methods were higher than GR and BK. The higher centre temperatures contributed positively to the textural properties of cooked meat. Samples cooked by DF method had higher fat, ash and chewiness contents due to oil absorption, uptake of soluble matters and impurity by the cooking samples from cooking oil and these caused softening effects by heat, solubilisation of meat connective tissues and conversion of collagen to gelatin.

The GR cooked samples had the least fat and ash contents due to drip losses and fat melting from the samples. Samples cooked by BK had higher carbohydrate content due to conversion of stored starch to dextrin and subsequently coated with browning colour. The best cooking method/ temperature/ time for low nutrient losses was BK, 170 $^{o}$C and 4 min.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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