Original Research Article

IMPACT OF COOKING METHODS ON PROXIMATE COMPOSITION AND MECHANICAL PROPERTIES OF CHICKEN BREAST MEAT

ABSTRACT

The impact of cooking on proximate composition and mechanical properties (cohesiveness and chewiness) of chicken breast meat was investigated. Eight packs of Industrial skinless chicken breast meat samples were purchased, frozen and sliced into dimensions, thawed and cooked by air frying (AF), baking (BK), deep fat frying (DF) and grilling (GR) at 170, 180 and 190 ^{0}C for 0, 4, 8, 12 and 16 min. The results showed that moisture content significantly ($p < 0.05$) reduced with increasing cooking time from75.14 to 47.40 %. Samples cooked by BK had the highest moisture content of 61.10 %, whereas the DF cooked samples had the least content of 55.82 %. Moisture content also significantly ($p < 0.05$) reduced with increases in cooking temperatures (from 60.58 to 56.34 %). Protein content reduced significantly ($p < 0.05$) with increased cooking times from 89.17 to 79.45 %. The AF had the highest protein content of 84.76 %, while DF had the least content of 79.15 %. Protein content reduced by cooking temperatures (from 83.77 to 82.11 %). Cooking temperatures and times increased ($p < 0.05$) fat and ash contents. Samples cooked by DF had the highest fat content of 11.88 %, while GR cooked samples had the least content of 5.87 %. Samples cooked by DF method had the highest ash content of 2.46 % and GR had the least content of 2.34 %. Cooking times increased significantly ($p < 0.05$) carbohydrate from 4.63 to 7.76 %. Bk had the highest carbohydrate content of 7.45 % and AF had the least content of 6.11 %. The results of mechanical properties showed that cooking temperatures and times increased significantly ($p < 0.05$) cohesiveness. Air fried samples had the highest content of 0.55, while deep fat fried samples had the least content of 0.48. Cooking temperatures and times increased significantly ($p < 0.05$) chewiness value. Samples cooked by DF method had the highest value of 6.99 kg, whereas BK cooked samples had the least value of 5.21 kg. There were no significant differences ($p > 0.05$) in chewiness values of samples cooked by AF and GR methods.

Keywords:

Cooking methods

Temperature

time

proximate

cohesiveness

chewiness

chicken breast

1.0 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 (2000). 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 Mead (2004), Sharma and Sharma (2011), Riovanto *et al.* (2012), Chumngeon and Tan (2015) and Alugwu *et al*. (2022). It has been reported by Sharma and Sharma (2011) 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.* (2023). The nutritional composition of chicken is influenced by variables like breed, feed, age, production method, sex and cooking method as reported by Joseph *et al*. (1997).

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 and esthetic value, nutritive, technological and hygienic quality attributes of the cooked products. It has been reported by Tornberg (2005) that cooking techniques affect structural changes and compositional components of cooked chicken. It may results in loss of heme iron from myoglobin thus increasing the possibility of lipid oxidation leading to rancidity in the product and other changes that occurred during cooking.

The proximate composition and textural method, which are concluded 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 Joseph *et al.* (1997). 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*. (2000) 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 mechanical properties on cooking methods of chicken breast. Hence, the aim of this study was to ascertain the effect of air frying (AF), baking (BK), deep fat frying (DF) and grilling (GR) methods on proximate composition, cohesiveness and chewiness properties of chicken breast meat.

2.0 Materials and Methods

2.1 Sample Preparation and Cooking process

Eight packs of external fat and connective tissues trimmed, skinless, boned fresh chicken meat were selected from a local grocery at St. Anne-de –Bellevue, Montreal, Canada transported to the Food and Bioprocess Laboratory of the Dept. of Bioresource Engineering, Macdonald Campus of McGill University in less than 30 min under cooled conditions. In the Laboratory, samples were frozen at -80 °C for 2 h to harden the muscle for easy slicing into 3.0 x 3.0 x 2.0 cm dimensions. Thereafter, the cut samples were divided into four cooking methods [air frying (AF), baking (BK), deep fat frying (DF) and grilling (GR)]. Each lot was further subdivided into three different cooking temperature regimes (170, 180 and 190 °C). For each temperature, the samples were cooked in each cooking methods for 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. The 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 analysis. All the cooking experiments were performed in duplicate and stored in freezer waiting for subsequent analysis.

2.2 **Proximate Composition of Chicken Breast Meat**

2.2.1 Determination of Moisture content

Moisture content of the samples was determined by the 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 °C for 24 h. The moisture dish was removed from the oven and cooled in desiccators to a constant weight (W_3). The dishes were weighed again, and percentage moisture content calculated as shown in eqn.1

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

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

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2.2.2 Freeze Drying Process and Determination of Protein Content

Frozen samples in Ziploc were transferred to sample tin dishes, covered with paraffin and frozen again for two hours. Thereafter, the paraffin's covers were perforated, and samples loaded in freeze dryer (Thermos) and set the temperature at-50 °C and dry it for three days. Total nitrogen content of the samples was determined using Dumas combustion method as described by Einarsson *et al*. (1983) and Alugwu et al (2023). Meat samples (raw meat, air fried, baked, deep-fat fried and grilled) were freeze-dried and ground with Cuisinart grinder to produce ground samples. A 50 mg ground 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 samples were heated rapidly at high temperature furnace in the presence of pure oxygen at 800 - 1000 °C 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). Thereafter, these combustion products were collected and allowed to equilibrate. The gas mixture was passed to hot copper to remove any oxygen and reduce other nitrogen oxides present to molecular nitrogen. The sample was passed through traps to enable the removal of water and carbon dioxide. The thermal conductivity detector signals were used to measure total nitrogen content converted from the samples by the difference in thermal conductivity. The conversion factor of 6.25 was used in the calculation of the protein content.

2.2.3 Determination of Fat Content.

Fat content of the samples was determined by Soxtec Method using standard methods of AOAC (2010). This technique employed six extracting cups and six thimbles in each operation. 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 into the solvent and the set-up locked, water inlet was opened, and machine switched on and the valves connecting the cups and condensers were closed at 104 °C, but at116 °C heating temperature, the immersion timing of 30 min display and time starts. Thereafter, at end of immersion timing, the thimbles were raised up from the solvent, indicator pointer shifted to washing and valves connecting the cup and condenser set closed and washed for

45 min. The valves connecting the cup and condensers were opened for the recovery of the solvent. An indicator pointer was switched immediately to the recovery and it lasted for 15 min. Thereafter, the cups were removed and cooled in desiccators. The weight of cup with oil was determined after cooling the flask in the desiccators (W_3) using eqn.2.

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

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 crucible containing the sample was placed in the Muffle furnace heated earlier previously at 600 °C and left for 6 h until the final product was clearly whitish ash. Thereafter, the crucible was removed from the Muffle furnace, placed in a desiccator and allowed to cool. Consequently, reweighed (W_3) and the ash content was calculated as shown in Eqn.3.

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

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).

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

2.3 Mechanical Assessment

Mechanical 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 (1978, 2002). The chicken muscle samples were cut into 3.0 x 3.0 x 2.0 cm and cooked at different temperatures and time intervals. Each sample was placed on the platform of the analyser connected to a computer (PC) for logging in of samples and subjected to double (two fold) compression cycle with 50 mm probe 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. The following 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. The analyser connected to a Personal computer (PC) for logging in of samples and subjected to double (two fold).

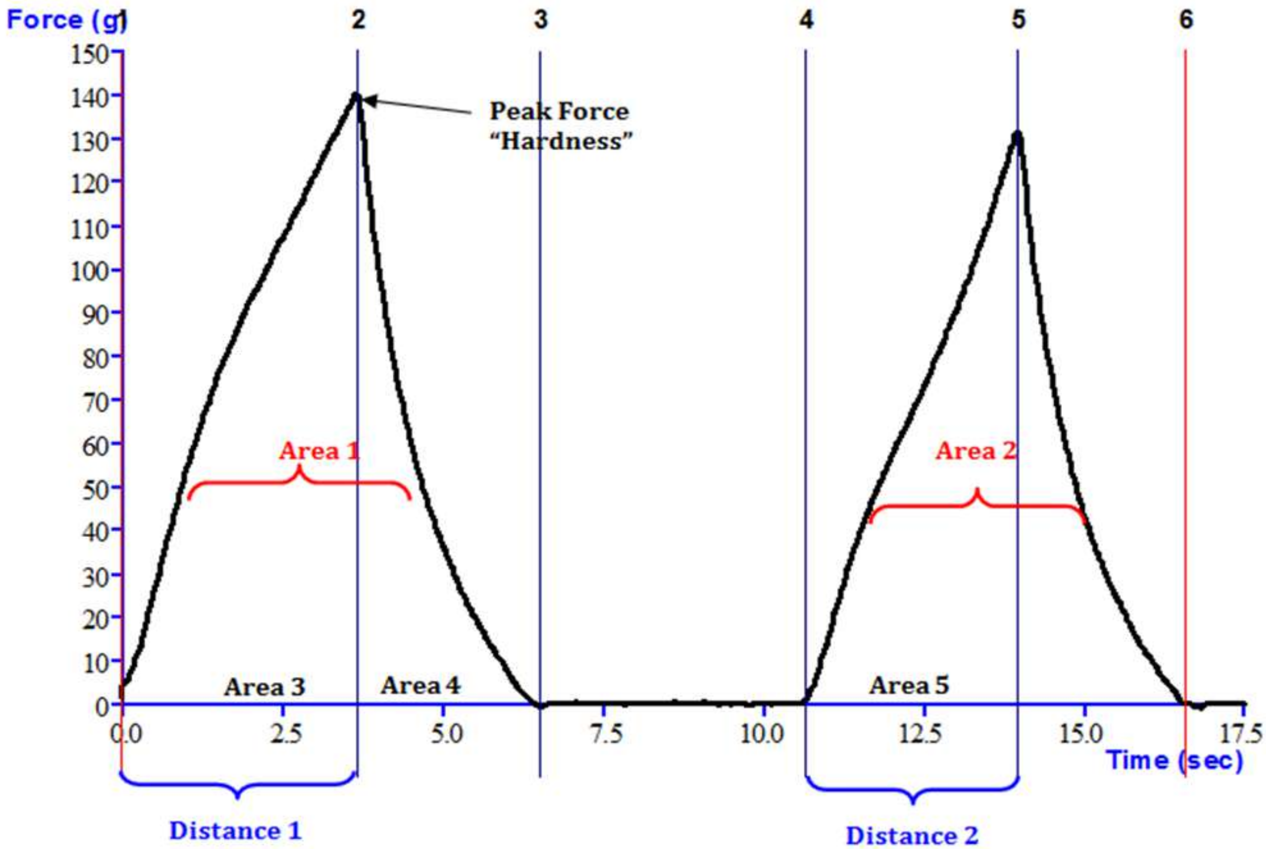

Fig. 1: Force – time (gram-sec).

Source: Bourne (1978)

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 analysis of variance (ANOVA) using IBM SPSS Statistics version 23.0 (IBM Corp. 2015) software package. The parameters measured were the proximate composition, and mechanical 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).

3.0 **Results and Discussion**

3.1 Proximate Composition **of Chicken Breast Meat**

3.1.1 **Changes in Moisture Content**

The results of moisture content of chicken breast meat cooked with different methods each at170, 180 and 190 °C 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 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*. (2007) 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, 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*. (2003). The findings of this research agree with Sigh and Verma (2000). The reduction of moisture content with increasing 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 increasing nor decreasing 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 increasing nor decreasing, 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 at190 ^{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 increasing 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 increasing nor decreasing 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

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

Cooking Method	Cooking Temp. °C	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

°C) were neither increasing nor decreasing with increase cooking times. Similarly, the differences between 180 and 190 °C (180 -190 °C) 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 190 °C and 16 min had the least moisture content (40.55 %), while the products obtained by baking at 170 °C 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 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 190 °C 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 (1992). 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 °C 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 °C gave average protein content of 83.77 %, at 180 °C, average protein content was 82.99 % and at 190°C, 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 (2014) 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 at190 ºC 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 (2011) and Alugwu (2018) have reported that heat application results in destruction of some amino acids, browning of products and reduction of protein content with increasing 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

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

	Cooking	Cooking time (min)					CM mean
Method	Temp. ℃	0	4	8	12	16	-
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 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 180 ºC (170 -180 ºC) or between 170 and 190 ºC (170 – 190 ºC) or between 180 and 190 ºC (180 -190 ºC) were neither increasing nor decreasing 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 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 Tables 3. The results in Table 3 showed that cooking increase 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*. (2009) and Hussain *et al.* (2013).

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 Steiner- Asiedu *et al.* (1991), Gokoglu *et al*. (2004) and Salawu *et al*. (2005), 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 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 180 ºC and 190 ºC. 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 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 increasing nor decreasing 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 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 ºC (170 – 180 ºC) or between 180 and 190 ºC (180 – 190 ºC) were neither increasing nor decreasing with increase cooking times. On the other hand, the differences in fat content between 170 and 190 ºC (170 – 190 ºC) were increasing 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 %.

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

This value was very high, indicating 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 °C 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 increase 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.* (2007), Achir *et al.* (2009) and Hussain *et al.* (2013) 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 (2012) 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 increasing nor decreasing 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 increases. 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 180 ºC (170 – 180 ºC), between 170 and 190 ºC (170 – 190 ºC) and between 180 and 190 ºC (180 – 190 ºC) 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 170 ºC and 4 min had the least ash content of 2.01 %, while the products obtained by deep fat frying at 190 ºC 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 treatment variables and their interactions affected the observed changes ash content

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

Cooking	Cooking	Cooking time (min)					Mean cooking	
Method	temp °C	0	4	8	12	16	temp °C	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

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3.1.5 Changes in Carbohydrates 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 (1985).

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 180 ºC (170 – 180 ºC) or between 170 and 190 ºC (170 – 190 ºC or between 180 and 190 ºC (180 – 190 ºC) were neither increasing or decreasing 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 75.1 %. This value was very high, indicating treatment variables and their interactions affected the observed changes in carbohydrate content.

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

Cooking	Cooking	Cooking time (min)					Mean cooking	
Method	temp ℃	0	4	8	12	16	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

3.2 **Changes in Mechanical Properties of Chicken Breast Meat**

3.2.1 **Changes in Cohesiveness**

The results of the changes in cohesiveness value 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 Pawar *et al*. (2002), Pandey *et al. (2014)* and Nithyalakshmi and Preetha (2015). 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 at190 °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 increasing 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 ($p < 0.05$) increase 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 ($p < 0.05$), 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 increasing with increase in cooking

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

Cooking Method	Cooking temp.^{0}C	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

times, but differences in between AF and DF (AF - DF) were decreasing 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 increasing nor decreasing 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 94.2 %. This value was very high, indicating treatment variables and their interactions affected the observed increases in cohesiveness content.

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 (2015) 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*. (2014) 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 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 increases 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*. (2014) who stated that chewiness of kebabs increases 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*. (2013). 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 in 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 increasing nor decreasing 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 increasing nor decreasing with increasing cooking times. Whereas, the differences in chewiness value between180 and 190 °C (180 – 190 °C) were increasing 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 treatment variables and their interactions affected the observed increases in chewiness value.

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

Cooking Method	Cooking temp.°C	Cooking time (min) 0	4	8	12	16	Mean 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

4.0 **Conclusion**

Cooking times significantly ($p < 0.05$) reduced moisture and protein contents from 75.14 to 58.25 % and 89.17 to 82.98 %, respectively. The least moisture and protein contents of samples cooked by deep fat frying method (DF) could be attributed to its higher cooking temperatures which caused the center of substrates to reach water boiling temperature at very short time of 1.5 min compared to air frying (AF) which takes longer time of 5.5 min. The higher cooking temperature of DF method resulted to higher melting fatty soluble substances, leaching into frying oil, thermal denaturation and losses of moisture. The moisture and protein contents decreased significantly ($p < 0.05$) with increases in cooking temperatures. Cooking times increased the fat content of chicken breast meat from 4.26 % to 7.78 %.The DF cooked samples had significantly ($p< 0.05$) the highest fat content of 11.88 , whereas the GR cooked samples had significantly ($p < 0.05$) the least content of 5.87 %. The least fat content of GR samples could be attributed to losses by drip losses as the fat melts from the samples. Cooking times increased ash content from 1.95 to 2.39 %. Samples cooked by DF method had the highest ash content of 2.46 % and GR method had the least content of 2.34 %. The higher ash content of DF cooked samples could be attributed to uptake of soluble matters and impurity by cooking materials from the cooking oil. Cooking temperatures increased significantly ($p < 0.05$) the fat and ash content of chicken breast meat from 10.97 to 12.70 % and 2.15 to 2.57 %, respectively. Cooking times increased significantly ($p < 0.05$) carbohydrate content from 4.63 to 6.95 %. The increases could be attributed to conversion of stored starch to dextrin and subsequently coated with browning colour. Samples cooked by BK method had the highest carbohydrate content of 7.45 %, while AF had the least content of 6.11%. The lower carbohydrate content of AF coked samples could be attributed to higher cooking temperature which converted stored starch to brown coatings. Cooking times increases the cohesiveness content from 0.40 to 0.52. Samples cooked by AF method had the highest cohesiveness content of 0.55, while samples cooked by DF method had the least content of 0.48.The increases of cohesiveness during cooking could be attributed to higher moisture losses from the product upsetting the viscoelastic behaviour of the products. There were no significant differences ($p > 0.05$) in cohesiveness content of samples cooked by AF and GR methods. Cooking times increased significantly ($p < 0.05$) the chewiness value from 3.63 to 6.05 kg. Samples cooked by DF had the highest chewiness value of 6.99 kg, but BK cooked samples had the least value of 5.21 kg. The increases in chewiness of cooked samples could be attributed to heat softening effects and solubilisation of meat connective tissues and conversion of collagen to gelatin. There were no significant differences in chewiness value of samples cooked by AF and GR methods. Cooking temperatures increased significantly ($p < 0.05$) the cohesiveness and chewiness of chicken breast meat from 0.50 to 0.55 and 5.50 to 6.77 kg, respectively.

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