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Effect of Thermal Treatments on Selected Minerals and Water Soluble Vitamins 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 study was conducted to ascertain the effect of thermal treatments on selected minerals (Ca, K, Mg, Na, P, Fe and Zn) and water soluble vitamins (B_1, B_2, B_3, B_6, B_9, B_{12} and C) contents of chicken breast meat. Industrial skinless chicken breast meat samples were purchased, transported to Bioprocess laboratory in cool conditions, frozen and sliced into dimensions and thawed. The samples were 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 and 12 min for minerals and 0, 8 and 16 min for vitamins. Thereafter, cooked and raw samples were wet acid digested overnight and 5 h digested on a block digester on slowly increased temperature to 120^{0}C, cooled and deionized. The mineral elements were analysed by Optima 4300DV inductivity coupled plasma optical emission spectrometry (ICP-OES) and inductivity coupled plasma mass spectrometry (ICP-MS). These mineral elements were extrapolated through a calibration curve between intensity and concentration, while the vitamins

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were ascertained by measurement of absorbance of filtrates of the samples dissolved in their respective solvents in the Spectrophotometer against their blank samples at different wavelengths. The results showed that cooking methods decreased significantly ($p < 0.05$) the mineral elements with an exception of Zn cooked by grilling (GR) that increased by 19.92% and Mg that increased in the cooking methods. The ascending percentage reduction of minerals in cooked chicken breast were Zn, P, K, Fe, Na and Ca. Samples cooked by DF had significantly ($p < 0.05$) higher percentage reduction of 45.06% in Ca, 27.74% in Na and 18.85% in Zn and higher percentage increases of 14.96% in Mg contents than other methods. Also samples cooked by DF had higher percentage reductions of 55.10%, 37.93%, 37.11%, 34.44% and 30.99% in vitamins B_1, C, B_2, B_9 and B_6 Whereas higher percentage reductions of 41.67% and 37.84 % in vitamins B_{12} and B_3 occurred in baking (Bk) and grilling (GR) treated samples. Cooking at 190^0C had higher percent reduction in the Ca, Na, Fe, K, P and Zn as well as B_1, B_{12}, B_2, C, B_3, B_9 and B_6. Cooking methods, temperatures and times decreased significantly ($p < 0.05$) vitamins and minerals contents of chicken breast meat with an exception of Mg. Samples cooked at 170^0C for 4 min and 170^0C for 8 min had lower losses of minerals and vitamins compared to similar samples cooked at 180^0C and 190^0C. The AF cooking method had the least percent reduction of 22.50% than other cooking methods BK (26.88%), DF (36.04%) and GR (30.69%) in vitamin contents.

Keywords: Air frying; baking; deep fat frying; grilling; vitamins; minerals; chicken.

1. INTRODUCTION

Chicken is an important commodity cherished and consumed in Nigeria. The proliferation of restaurants and food service centers has greatly increased its consumption. Chicken breast is special muscle with less application in birds' physical activity and birds with increased growth rate have heavier breast muscle with thick fibre. It is leaner (< 3g fat/100g) than other muscles as well as supplies higher quality protein with mild flavour and versatility. Chicken has been reported to be a healthier meat because it has low cholesterol, low content of saturated fatty acids, good sources of amino acids [1] and mineral elements. The minerals and B- vitamins which are indispensable for health, growth of body cells, protection against infective and degenerative diseases as well as contribute adequately to human micronutrients daily requirements [2,3] and (Kim et al. 2015). Chicken meat has also been reported to constitute on wet bases 74% moisture, 23% protein, and 1.2% fat by Sharma and Sharma [2]. Chicken is comparable to red meats and fish in composition and nutritive value. It has been reported by Leskova et al. (2003) that vitamins are unstable in foods. Of all the nutrients in chicken flesh, water soluble vitamins and minerals are most susceptible to loss or destruction by Processing and cooking conditions. It is known that after heat treatments heme iron is converted to a different extent into non-heme iron, the less available form of iron [4]. The rate of loss depends on cooking methods, type of food and duration of cooking. Barbanti and Pasquini (2004) investigated the influence of cooking conditions at three temperatures (130, 150 and 170^0C) and three different time periods (4, 8 and 12 min) on cooking loss and tenderness of raw and marinated chicken breast meat. The temperature and time of cooking showed similar effects on cooking loss and tenderness. It was also observed that temperatures (130 – 150^0C) and cooking time (4 min) resulted to lower cooking losses and best meat tenderness. Moreover, Kumar et al. [5] investigated the kinetics of change in quality parameters of fried Khaja at different frying temperatures (160–200°C) and time (1–5 min). It was observed that the lightness of the Khaja decreased from 82.80 to 58.09 – 46.04, while the redness parameter increased from 0.42 to 5.63 – 11.11 for the samples fried for 5 min, at different temperatures. The yellowness parameter increased with time at lower temperatures (160 – 170^0C). The hardness and moisture content of the samples decreased, whereas the total fat increased after 5 min frying. Microstructural changes were associated with cellular collapse and gelatinization.

Chicken nutritional composition is also influenced by variables like breed, feed, age, production method, sex and cooking conditions as reported by Joseph et al. [6]. Thermal processing results in loss of its large mass as meat juice. Large quantity of meat juice is water. It has been reported by Oillic et al. [7] that micronutrients can flow with cooking juice, thereby reducing the nutritional quality of processed product. Air frying cooks muscles by continuous flowing of hot air steam around the cooking muscles through

sparging form instead of immersing the muscles in the hot cooking oil as in deep fat frying. Whereas baking is done in an enclosed oven with hot air and products are cooked by heated air circulating inside the oven by convection; heat radiating from metallic structure of the oven and conduction of heat from the direct contact of chicken with the baking trays [7,9]. Grilling method is a quick method of cooking that uses thermal radiation heat transfers to cook samples placed on the grill. It uses smokeless flames in cooking its products through radiation rays and conduction through grill bars. It also gives great flavour to its cooked products [10,11]. Hence, the cooking temperatures of study were elevated from 170 to 190^{0}C to study their effect on selected minerals (Ca, K, Na, Mg, P, Fe and Zn) and water soluble vitamins (B_1, B_2, B_3, B_6, $B_{9,}$ B_{12} and C), which are some micronutrients in cooked chicken products coupled with the fact that there is paucity of information concerning how cooking conditions affect these minerals and vitamins. These nutrients are also importance to human health.

2. MATERIALS AND METHODS

2.1 Sample Preparation and Cooking Process of Chicken Breast Meat

Nine packs of skinless, boned chicken breast (pectoralis major) muscles were randomly selected from (a local grocery store) in St. Anne – de -Bellevue, Montreal, Canada. These muscle packs were transported to the Food and Bioprocess Laboratory of the Dept. of Bioresource Engineering, Macdonald Campus of McGill University within 30 min under cooled conditions. In the Laboratory, samples were frozen at -80^{o}C for 2 h to harden the muscle for easy slicing into 3.0 x 3.0 x 2.0 cm. Thereafter, the cut samples were divided into four cooking methods (air frying (AF), baking (BK), deep fat frying (DF) and grilling (GR)). Each portion of the cooking method was further subdivided into three different cooking temperature regimes (170, 180 and 190^{o}C) and each temperature portion was subdivided further into four different time intervals (0, 4, 8 and 12 min). Samples were then weighed before cooking. Samples for deep fat frying were cooked with four (4) litres of canola oil, which was previously preheated at 170℃ for 2 h before its application. While other cooking materials (Air fryer, baking and griller) were preheated to desired temperature for 20 min prior to cooking and thereafter, each cooked sample was allowed to cool for 30 min at room temperature.

The uncooked breast meat was used as the control sample. Samples for air frying was carried out with Philips Air fryer (Model HD 9225), baking and grilling were done using a Black and Decker digital 4-in-1 oven (SKU: TO1303SU/ FABRICADO EN/ CHINA) and Deep fat frying was conducted with Delonghi (Type: D24527 DZ, Made in China) equipment. All samples after cooking and cooling were wrapped in aluminum foil and packaged in Ziplock bag and frozen. Thereafter, the Ziplock frozen samples were transferred to sample tin dishes, covered with paraffin and frozen again for two hours. Subsequently, the paraffin's covers were perforated, and samples loaded in freeze dryer (Thermos) and set the temperature at-50^{0}C and dry it for three days.

The freeze dried meat samples (raw meat, air fried, baked, deep-fat fried and grilled) were ground with Cuisinart grinder to produce ground samples. These samples, which were stored in refrigerator for minerals (Ca, K, Na, Mg, P, Fe and Zn) and vitamins (B_1, B_2, B_3, B_6, $B_{9,}$ B_{12} and C) analysis.

2.2 Determination of Mineral Contents of the Samples

Mineral elements of the raw and cooked samples were determined using the wet acid digestion procedure described by AOAC (2010). A 0.16g of each of these samples was weighed into 15-mL digestion tubes; 2 mL of 70% HNO_3 was added and left overnight. Thereafter, the tubes were placed on a block digester, the temperature was gradually increased to 120^{0}C, and the samples were digested for 5 h.

The samples were cooled for 15 min and transferred into 50-mL Falcon tubes. Thereafter, 48 mL double deionized water was added; and the Falcon tubes were capped and stored until further analysis. The minerals Calcium, Phosphorus, Potassium, Magnesium and Sodium were analyzed using an Optima 4300DV inductivity coupled plasma optical emission spectrometry (ICP-OES) and inductivity coupled plasma mass spectrometer (ICP-MS) for iron and Zinc**.** The mineral ions were ascertained through a calibration curve between intensity and concentration as shown in Fig. 1 for potassium (K). The resulting equation was used to obtain

the concentrations in the samples and then calculate the concentration by mass.

2.3 Determination of Vitamins

2.3.1 Determination of Vitamin B_1 (Thiamine)

The vitamin B_1 content of the samples was determined as described by AOAC [12]. The meat samples were pulverized and a 0.2 g of each pulverized sample was weighed into different test tubes and each sample was homogenized with 5 mL ethanoic sodium hydroxide. Thereafter, the mixture was filtered and 2 mL potassium dichromate (K_2CrO_7) added to the filtrate and allowed to stand for 10 min for colour development. Thereafter, the absorbance was measured at 560 nm against a blank and standard of vitamin B_1.

2.3.2 Determination of vitamin B_2 (Riboflavin)

The Vitamin B_2 content of the samples was determined as described by AOAC [12]. The meat samples were pulverized and a 0.2 g of each pulverized sample was weighed into different test tubes with an addition of 2 mL of 4 % sodium sulphate and 10 mL of distilled water to the mixture. The mixture was incubated at 30^0C for 2h. Thereafter, the absorbance was measured at 510 nm against blank and standard of vitamin B_2 in a spectrophotometer.

2.3.3 Determination of vitamin B_3 (Niacin)

The vitamin B_3 content of the samples was determined as described by AOAC [12]. The meat samples were pulverized and a 0.2 g of each pulverized sample was weighed into different test tubes. Thereafter, 5 mL of 1 N H_2S0_4 was added to the sample in the different test tubes and mixture was shaken intermittently for 30 min and refluxed. Consequently, 3 drops of ammonia solution were added and filtered. The mixture was acidified with 1 mL of Conc. H_2S0_4 if there was no visible colour change, but if there was acidic colour change of either dark or brown, there was no need to acidify the mixture, rather the mixture was allowed to stand for 10 min. Thereafter, the absorbance was measured at 560 nm.

2.3.4 Determination of vitamin B_6 (Pyridoxine)

The vitamin B_6 content of the samples was determined as described by AOAC [12]. The meat samples were pulverized and a 0.2 g pulverized sample was weighed into different test tubes. Thereafter, 2 mL of distilled water was added to the sample with 0.4 mL of 5% sodium acetate and 0.2 mL of 5.5% sodium carbonate in the different test tube. Subsequently, the absorbance was measured at 540 nm against standard and blank.

2.3.5 Determination of vitamin B_9 (Folic acid)

The Vitamin B_9 was determined as described by AOAC [12]. The meat samples were pulverized and 0.2 g pulverized sample was weighed into a 250 mL beakers and 10 mL of distilled water was added to the sample in the different beakers. The mixture in the different beakers was shaken and allowed to settle, centrifuged at 3000 rpm for 10 min. Thereafter, the upper layer was decanted, and absorbance was measured at 379 nm with Ultraviolet spectrophotometer.

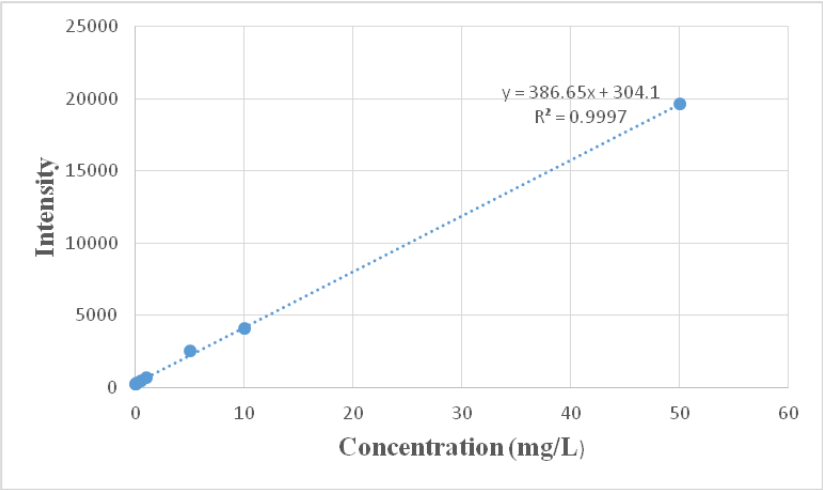

Fig. 1. Calibration curve for K determination

2.3.6 Determination of Vitamin B_{12} (Cyanocobalamin)

The Vitamin B_{12} was determined as described by AOAC [12]. The meat samples were pulverized and 0.2 g pulverized sample was weighed into a test tube and 100 mL of distilled water was added to each of the sample in different test tubes. The mixture was shaken and allowed to settle, the upper layer was decanted, and the absorbance measured at 274 nm with Ultraviolet spectrophotometer.

2.3.7 Determination of vitamin C (Ascorbic acid)

The Vitamin C of the samples was determined as described by AOAC [12]. The meat samples were pulverized and 0.2 g pulverized sample was weighed into a test tube. Consequently, 4 mL of 0.4 % Oxalic acid and 1 mL of Conc. H_2S0_4 were added to each of the samples in different test tubes and allowed to cool. Thereafter, 2 mL of ammonium molybdate and 3 mL of distilled water were added to the test tubes. The mixture in the test tubes was shaken and allowed to stand for 15 min. Subsequently, the absorbance of the supernatant was measured at 760 nm.

2.4 Statistical Analysis

The research study was a 4 x 3 x 4 factorial experiment as described by Obi [13] in completely randomized design (CRD). All experiments were performed in duplicate. The results are expressed as mean ± standard deviations and analysed using the General linear model procedures of IBM Statistical Package of Social Sciences [14] version 23. 0. Data subjected to two- way analysis of variance (ANOVA) and mean comparison was performed at ($p < 0.05$) using Duncan's New Multiple Range Test (DNMRT).

3. RESULTS AND DISCUSSION

3.1 Changes in Mineral Contents

3.1.1 Changes in mineral contents of chicken breast meat

The results of Ca, K, Mg, P, Na, Fe and Zn contents of chicken breast meat cooked at different methods each at 170, 180 and 190 ℃ for 0, 4, 8 and 12 min are shown in Tables 1, 2, 3, 4, 5, 6, and 7, respectively. The results in Tables 1,2,4,5, 6 and 7 showed that cooking reduced the Ca, K, P, Na, Fe and Zn content. While Table 3 showed that cooking increased Mg content of chicken breast meat. On the average, Ca, K, P, Na, Fe and Zn contents reduced to an overall mean of 194.42, 14,451.91, 7,896.20, 2,248.77, 12.42 and 30.34 mg/Kg, but increased Mg overall mean content of 1496.85 mg/Kg.

Cooking methods significantly ($p < 0.05$) affected Ca content. The results in Table 1 showed that samples cooked by air frying (AF) had an average Ca content of 180.23 mg/Kg, while samples cooked by baking (BK) had 203.83 mg/Kg, deep fat frying (DF) had 164.98 mg/Kg and grilling (GR) had mean Ca content of 228.64 mg/Kg. The differences in Ca content due to cooking methods were significant ($p < 0.05$) and GR cooked samples had significantly ($p <0.05$) higher Ca content than others. The lower Ca content of DF cooked samples compared to others could be attributed to leaching effect of Ca into the cooking oil. This finding is not in accordance with reported result by Menezes et al. [15] who reported BK as the highest losses of Ca for cooked chicken meat.

Cooking temperature significantly ($p < 0.05$) affected Ca content of cooked chicken breast meat. As shown in Table 1, the average Ca content at 170, 180 and 190℃ were 205.23 mg/Kg, 196.12 mg/Kg and 181.95 mg/Kg. Thus, Ca content significantly ($p < 0.05$) reduced with increase in cooking temperature. The differences in Ca content caused by cooking temperatures were significant. Cooking at 170℃ resulted to significantly ($p < 0.05$) higher Ca content than cooking at 180℃ and 190℃. Heat emanating from the cooking induced oxidation effects on Ca bonded to denatured proteins. This result is in line with reports of Lawrie and Ledward [16] who reported that cooking reduced Ca content of cooked beef.

The reduction of Ca content with increasing temperature could be attributed to oxidation effects on Ca bonded to denatured proteins. The interaction between cooking methods and temperatures was significant ($p < 0.05$), suggesting that the differences in Ca content caused by the temperature were different at different temperature. It could be deduced from Table 1 that the differences in Ca content between AF and DF (AF – DF) and BK and GR (BK - GR) samples decreased with increase in cooking temperatures. On the other hand, the differences in Ca 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 Ca content between BK and DF (BK – DF) and DF and GR (DF – GR) were each neither increasing nor decreasing, respectively with increase in cooking temperatures. From this interaction, it is deduced that DF method resulted to least Ca content at each cooking temperature compared to other cooking methods. This may suggest that, in addition to moisture loss, more Ca were leached into the frying oil with the leaching being higher at higher temperatures. Although all products continued to reduce in Ca content as temperature of cooking increased, the grilled (GR) products had the highest Ca content at each cooking temperature, suggesting that there was less loss of Ca at each temperature compared with other cooking methods.

The results in Table 1 showed that cooking time affected Ca content. The average Ca content at 4, 8 and 12 min were 187.38 mg/Kg, 158.60 mg/Kg mg/Kg and 131.43 mg/Kg, respectively. Thus Ca 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 Ca content due to the cooking methods were different at different cooking times. The significant interaction ($p < 0.05$) showed that the differences in Ca content between AF and BK (AF - BK) were decreasing with increase in cooking time, but the Ca content differences between AF and DF (AF - DF), AF and GR (AF – GR), BK and DF (BK - DF) and BK and GR (BK - GR) were neither increasing nor decreasing with increase in cooking time, while the differences between DF and GR (DF – GR) were increasing with increase in cooking time. The results showed that the interaction between cooking temperatures and cooking times were significant ($p < 0.05$), suggesting that the differences in Ca between170 and 180°C (170 - 180°C) and 170 and 190°C (170 -190°C) were increasing with increase cooking times. Whereas the differences in Ca between 180 and 190°C (180 - 190°C) were neither increasing nor decreasing with increase in cooking time. However, the overall interaction (Method x Temperature x Time) was found to be significant. This significant ($p < 0.05$) overall interaction confirm why the products of deep fat fried (DF) at 190℃ and 12 min had the least Ca content (75.07 mg/Kg), while the products obtained by grilling (GR) at 170℃ for 4 min had the highest Ca content (237.66 mg/Kg). The coefficient of determination R^2 is 99.9 %. This value is very high, indicating treatment variables and their interactions affected the observed decreases in Ca content.

The results in Table 2 showed that cooking reduced the K content of chicken breast meat. On the average, K content reduced to an overall mean of 14,451.91 mg/Kg. This reduction in K content by cooking methods could be attributed to the stripping action of K ions from the substrate into the cooking medium. Cooking methods significantly ($p < 0.05$) affected K content. It was observed in Table 2 that samples cooked by air frying (AF), baking (BK), deep fat frying (DF) and grilling (GR) had an average K content of 14,371.46 mg/Kg, 14,433.15 mg/Kg, 14413.76 mg/Kg and 14589.26 mg/Kg, respectively. The differences in K content due to cooking methods were significant ($p < 0.05$) and samples cooked by GR had significantly ($p <0.05$) higher K content than others. The lower K content of DF compared to others could be attributed to the stripping action of K ions from the substrate and subsequent formation of alkaline soap with the frying oil as reported by Blumenthal et al. (1985).

Cooking temperature significantly ($p < 0.05$) affected K content of cooked chicken breast meat. Cooking at 170, 180 and 190℃ gave average K content of 14,737.00 mg/Kg, 14,436.97 mg/Kg and 14,181.76 mg/Kg. Thus, K content significantly ($p < 0.05$) reduced with increase in cooking temperature. The differences in K content caused by cooking temperatures were significant ($p< 0.05$). Cooking at170℃ resulted to significantly ($p < 0.05$) higher K content than cooking at 180℃ and 190℃. The reduction of K content with increasing temperature could be attributed to stripping actions of cooking medium. The results are in accordance with the findings of Purchas et al. [17] who found that cooking decreased K concentration in cooked lean New Zealand beef and lamb. The interaction between cooking methods and temperatures was significant ($p < 0.05$), suggesting that the differences in K content caused by the temperature were different at different cooking time. It could be deduced from Table 2 that the differences in K content between BK and DF (BK – DF) samples decreased with increase in cooking temperatures. On the other hand, the differences in K content between AF and BK (AF –BK) or between AF and DF (AF – DF), or between AF and GR (AF – GR) or between BK and GR (BK –

GR) or between DF and GR (DF – GR) were neither increasing nor decreasing, respectively with increase in cooking temperature. From this interaction, it is deduced that DF method resulted to least K content at each cooking temperature compared to other cooking methods. This may suggest that, in addition to moisture loss, soluble substances and K content in meat were stripped and leached into the frying oil with the leaching being higher at higher temperatures. Although all products continued to reduce in K content as temperature of cooking increased, the grilled (GR) products had the highest K content at each cooking temperature, suggesting that there was less stripping of K content and drip loss at each temperature compared with other cooking methods.

The results in Table 2 showed that cooking time affected K content. The average K content at 4, 8 and 12 min were 14,256.05 mg/Kg, 13,787.64 mg/Kg and 13,090.82 mg/Kg. Thus K 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 ($p < 0.05$). This suggest that the K content due to the cooking methods were different at different cooking times. The significant interaction ($p < 0.05$) showed that the differences in K content between AF and BK (AF - BK) and DF and GR (DF - GR) were decreasing with increase in cooking time, but the differences in K content between AF and DF (AF - DF) or AF and GR (AF – GR) or BK and DF (BK - DF) or BK and GR (BK - GR) were neither increasing nor decreasing with increase in cooking time. The results showed that the interaction between cooking temperatures and cooking times was significant ($p < 0.05$), suggesting that the differences in K content between 170 and 180°C (170 - 180°C) or between 180 and 190°C (180 - 190°C) were neither increasing nor decreasing with increase cooking time. On the other hand, the differences between 170 and 190°C (170 and 190°C) were increasing with increase cooking time. However, the overall interaction (Method x Temperature x Time) was found to be significant. This significant ($p < 0.05$) in overall interaction confirm why the products air fried (AF) at 190℃ and 12 min had the least K content (12302.57 mg/Kg), while the products obtained by baking at 170℃ for 4 min had the highest K content (14905.19 mg/Kg). The K coefficient of determination R^2 is 99.8 %. This value is very high, indicating treatment variables and their interactions affected the observed decreases in K content.

The results in Table 3 showed that cooking increased the Mg content of chicken breast meat. Cooking methods significantly ($p < 0.05$) affected Mg content. It was observed in Table 3 that samples cooked by air frying (AF) had an average Mg content of 1426.75 mg/Kg, samples cooked by baking (BK) had 1515.04 mg/Kg, deep fat frying (DF) had 1535.89, while grilling (GR) had mean Mg content of 1509.72 mg/Kg. Cooking methods increase Mg content of cooked chicken breast compared to raw value. Magnesium is a structural components [18] in bones, teeth and flesh of chicken and cooking increases the bioavailability of magnesium in cooked chicken breast. The differences in Mg content due to cooking methods were significant ($p < 0.05$) and samples cooked DF had significantly ($p <0.05$) higher Mg content than others. The higher Mg content of DF compared to others could be attributed to absorption of soluble and impurity from the frying oil as well as higher concentration of the cooking oil temperature. The increased in Mg content of cooked samples agreed with the findings by Rosa et al. [19] and Erosy and Ozeren [20] who reported that Mg content increased significantly during cooking of African catfish. However, OZ et al. [21] reported decreased in Mg content in cooked beef steak. Cooking temperature significantly ($p < 0.05$) affected Mg content of cooked chicken breast meat. As shown in Table 3, cooking at 170, 180 and 190℃ gave average Mg content of 1450.83 mg/Kg, 1484.42 mg/Kg and 1555.31 mg/Kg, respectively. Thus, Mg content significantly ($p < 0.05$) increased with increase in cooking temperatures. The Mg content of cooking temperatures (170, 180 and 190℃) increased by 8.56 %, 11.08 % and 16.38 %, respectively in its bioavailability after cooking. The differences in Mg content caused by cooking temperatures were significant ($p< 0.05$). Cooking at 190℃ resulted to significantly ($p < 0.05$) higher bioavailability of Mg content than cooking at 170℃ and 180℃). This finding agrees with similar findings presented by Karakoke et al. (2010) which had 48.54 ppm in breast meat and meat samples respectively. The increase in Mg content with increasing temperature could be attributed to higher rate of bioavailability of Mg in cooked chicken breast. The interaction between cooking methods and temperatures was significant ($p < 0.05$), suggesting that the differences in Mg content caused by the cooking temperature were different at different cooking

method. It could be deduced from Table3 that the differences in Mg content between AF and BK (AF – BK), BK and GR (BK – GR) and DF and GR (DF- GR) samples decreased with increase in cooking temperatures. On the other hand, the differences in Mg content between AF and DF (AF –DF) or between AF and GR (AF – GR) or between BK and DF (BK – DF) were neither increasing nor decreasing with increase in cooking temperatures. From this interaction, it is deduced that DF method resulted to higher Mg content at each cooking temperature compared to other cooking methods, with the AF method causing the least Mg content at 190℃ cooking temperature. This may suggest that, in addition to soluble substances in the frying oil more concentration and improved bioavailability higher at higher temperatures. Although all products continued to increase in Mg content as temperature of cooking increased, the deep fat fried (DF) products had the highest Mg content at each cooking temperature, suggesting that there was concentration effects at each cooking temperature compared with other cooking methods.

The results in Table 3 showed that cooking time affected Mg content. The averaged Mg content at 4, 8 and 12 min were 1485.76 mg/Kg, 1563.18 mg/Kg and 1601.92 mg/Kg. Thus Mg content significantly ($p < 0.05$) increased as cooking times 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 significant ($p < 0.05$), suggesting that the Mg content due to the cooking methods were different at different cooking times. The significant interaction ($p < 0.05$) show that the differences in Mg 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 Mg content between AF and DF (AF - DF) or between BK and DF (BK - DF) or BK and GR (BK - GR) were neither increasing nor decreasing with increase in cooking times and differences in Mg content between DF and GR (DF – GR) were decreasing with increase in cooking times. The results showed that the interaction between cooking temperatures and cooking times was significant ($p < 0.05$). This suggest that the differences in Mg content between 170 and 180°C (170 - 180°C) or between 180 and 190°C (180 - 190°C) were neither increasing nor decreasing with increase cooking times. While the differences in Mg content between 170 and 190°C (170 - 190°C) were decreasing with increase cooking times. However, the overall interaction (Method x Temperature x Time) was not significant. The coefficient of determination R^2 is 96.6 %. This value is very high, indicating treatment variables and their interactions affected the observed increases in Mg content.

The results in Table 4 showed that cooking decreased the P content of chicken breast meat. Cooking methods significantly ($p < 0.05$) affected P content. It was observed in Table 4 that samples cooked by air frying (AF) had an average P content of 8027.54 mg/Kg, samples cooked by baking (BK) had 7985.92 mg/Kg, deep fat frying (DF) had 7798.67 mg/Kg, while grilling (GR) had mean P content of 7772.67 mg/Kg. Cooking method decreased P content of chicken breast meat samples significantly ($p < 0.05$). This finding confirms reported findings by Lopes et al. [22] and Oz et al. [23] who reported that cooking strongly influences mineral content of meat as well as affected their eating by consumers. The differences in P content due to cooking methods were significant ($p < 0.05$) and samples cooked by AF had significantly ($p <0.05$) higher P content than DF and GR cooked samples, but not significant ($p > 0.05$) with samples cooked by BK method. The lower P content of GR cooked samples compared to others could be attributed to higher melting fatty soluble substances and dripping out from the cooking samples into the cooking medium. However, there was no significant different ($p > 0.05$) between P content of samples cooked by GR and DF methods.

Cooking temperature significantly ($p < 0.05$) affected P content of cooked chicken breast meat. Table 4 showed that Average P contents in cooking at 170, 180 and 190℃ were 8022.50 mg/Kg, 7924.53 mg/Kg and 7741.56 mg/Kg, respectively. Thus, P content significantly ($p < 0.05$) reduced with increase in cooking temperatures. The differences in P content caused by cooking temperatures were significant ($p< 0.05$). Cooking at 170℃ resulted to significantly ($p < 0.05$) higher P content than cooking at 180℃ and 190℃. Heat emanating from the cooking induced structural and compositional denaturation of proteins, release and losses of phosphate. The reduction of P content with increasing temperature could be attributed to higher rate of loss of moisture and phosphate. The interaction between cooking methods and temperatures was significant ($p < 0.05$), suggesting that the differences in P content caused by the temperature were different

at different cooking temperature. It could be deduced from Table 4 that the differences in P content between AF and DF (AF – DF) and BK and DF (BK – DF) samples decreased with increase in cooking temperatures. On the other hand, the differences in P content between AF and BK (AF –BK) or between AF and GR (AF – GR) or between BK and GR (BK –GR) or DF and GR (DF – GR) were neither increasing nor decreasing with increase in cooking temperatures. From this interaction, it is deduced that GR method resulted to least P content at 180°C and 190°C cooking temperature compared to other cooking methods. This may suggest that, in addition to moisture loss, more fat soluble substances and phosphates in meat were drip out to the cooking medium. Although all products continued to reduce in P content as temperature of cooking increased, the air fried (AF) products had the highest P content at 170°C and 180°C cooking temperature, suggesting that there was less fat drip loss and P loss at these temperatures compared to other cooking methods.

The results in Table 4 showed that cooking time affected P content. The average P content at 4, 8 and 12 min were 7752.54 mg/Kg, 7498.88 mg/Kg and 7338.38 mg/Kg. Thus P content significantly ($p < 0.05$) reduced as cooking times 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 P content due to the cooking methods were different at different cooking times. The significant interaction ($p < 0.05$) showed that the differences in P content between AF and BK (AF - BK) were increasing with increase in cooking times. On the other hand, differences in P content between AF and DF (AF - DF) or between AF and GR (AF - GR) or between BK and DF (BK - DF) or between BK and GR (BK - GR) or between 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 significant ($p < 0.05$), suggesting that the differences in P content between 170 and 180°C (170 - 180°C) and between 170 and 190°C (170 - 190°C) were decreasing with increase in cooking times. On the other hand, the differences between 180 and 190°C (180 - 190°C) were neither increasing nor decreasing with increase cooking times. However, the overall interaction (Method x Temperature x Time) was found to be significant. This significant ($p < 0.05$) overall interaction confirm why the products grilled (GR) at 190℃ and 12 min had the least P content (7005.50 mg/Kg), while the products obtained by air fried(AF) at 170℃ for 4 min had the highest P content (8259.00 mg/Kg). The P coefficient of determination R^2 is 99.3%. This value is very high, indicating treatment variables and their interactions affected the observed decreases in P content.

The results of Table 5 showed cooking methods decreased the Na content of chicken breast meat. It was observed in Table 5 that samples cooked by air frying (AF) had an average Na content of 2080.12 mg/Kg, those cooked by baking (BK) had 2365.74 mg/Kg, deep fat frying (DF) had 2069.48 mg/Kg, while grilling (GR) had mean Na content of 2479.75 mg/Kg. The differences in Na content due to cooking methods were significant ($p < 0.05$) and samples cooked by GR had significantly ($p <0.05$) higher Na content than others. The lower Na content of DF compared to others could be attributed to stripping action of its ions into the frying oil and formation of alkaline soaps. This similar finding was reported by Blumenthal et al. (1985) who stated that stripped Na^+ ions promotes oxidation.

Cooking temperature significantly ($p < 0.05$) affected Na content of cooked chicken breast meat. The average Na contents cooking at 170, 180 and 190℃ were 2415.55 mg/Kg, 2279.77 mg/Kg and 2065.05 mg/Kg. Thus, Na content significantly ($p < 0.05$) reduced with increase in cooking temperature. The differences in Na content caused by cooking temperatures were significant ($p< 0.05$). Cooking at170℃ resulted to significantly ($p < 0.05$) higher Na content than cooking at 180℃ and 190℃. The lower Na content of DF method could be attributed to stripping of Na ion from substrate by the frying oil and consequent formation of alkaline soap. The results of this finding are in accordance to the results of Purchas et al. [17] who observed Na contents of cooked and uncooked lean beef and found that cooking decreased in Na content of the substrates. The Na enters human system also by variety of foods such cheese, breads and processed foods. The reduction of Na content with increasing temperature could be attributed to higher oxidation of denatured protein and bounded Na content. The interaction between cooking methods and temperatures was significant ($p < 0.05$), suggesting that the

differences in Na content caused by the temperature were different at different cooking temperature. It could be deduced from Table 5 that the differences in Na content between AF and BK (AF – BKF), between AF and GR (AF – GR) and between DF and GR (DF – GR) cooked samples increased with increase in cooking temperatures. On the other hand, the differences in Na content between AF and DF (AF– DF) or between BK and DF (BK – DF) or between BK and GR (BK –GR) were neither increasing nor decreasing with increase in cooking temperatures. From this interaction, it is deduced that DF method resulted to least Na content at 170℃ and 180℃ cooking temperatures compared to other cooking methods, with the AF method producing the least Na content at190 ℃ cooking temperature. This may suggest that, oxidation of denatured protein and bonded Na, was being higher at higher temperatures. Although all products continued to reduce in Na content as temperature of cooking increased, the grilled (GR) products had the highest Na content at each cooking temperature, suggesting that there was less oxidation of denatured protein and drip loss of Na content at each temperature compared to other cooking methods.

The results in Table 5 showed that cooking time affected Na content. The average Na contents at 4, 8 and 12 min were 2336.36 mg/Kg, 2025.19 mg/Kg and 1769.70 mg/Kg. Thus Na 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 ($p < 0.05$). This suggests that the Na content due to the cooking methods were different at different cooking times. The significant interaction ($p < 0.05$) showed that the differences in Na content between BK and DF (BK- DF), between BK and GR (BK – GR) and between DF and GR (DF – GR) were decreasing with increased in cooking times, but the differences in Na content between AF and BK (AF – BK) or AF and GR (AF - GR) were neither increasing nor decreasing with increased in cooking times. On the other hand, the differences between AF and DF (AF - DF) were increasing with increasing 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 Na content between170 and 180°C (170 - 180°C) or between 180 and 190°C (180 - 190°C) were neither increasing nor decreasing with increased in cooking times. On the other hand, the differences between 170 and 190°C (170 - 190°C) were increasing with increased in cooking times. However, the overall interaction (Method x Temperature x Time) was found to be significant. This significant ($p < 0.05$) overall interaction confirm why the products air fried (AF) at 190℃ for 12 min had the least Na content (1278.69 mg/Kg), while the products obtained by grilled at 170℃ for 4 min had the highest Na content (2809.21 mg/Kg). Though Na is good health practice in our meals and for taste, excessive consumption is not encouraged. It has been reported to be dangerous to our health and it has a correlation effect on hypertension by OZ et al. [23]. The Na coefficient of determination R^2 is 99.9%. This value is very high, indicating treatment variables and their interactions affected the observed decreases in Na content.

Table 6 showed the Fe content of chicken breast meat. Cooking methods significantly ($p < 0.05$) affected Fe content. It was observed in Table 6 that samples cooked by air frying (AF) had an average Fe content of 11.83 mg/Kg, those cooked by baking (BK) had 12.95 mg/Kg, deep fat frying (DF) had 12.67 mg/Kg, while grilling (GR) had mean Fe content of 12.24 mg/Kg. The differences in Fe content due to cooking methods were significant ($p < 0.05$). The lower Fe content of cooked samples could be attributed to denaturation of myoglobin molecules. Iron is naturally present in the soil but translocated to chicken breast meat through drinking water and eating of feed (plant and animal materials) and cooking decreased significantly ($p < 0. 05$) iron content of cooked chicken breast meat samples.

Cooking temperature significantly ($p < 0.05$) affected Fe content of cooked chicken breast meat. Table 6 shows that average Fe contents in cooking at 170, 180 and 190℃ were 13.20 mg/Kg, 12.34 mg/Kg and 11.73 mg/Kg. Thus, Fe content significantly ($p < 0.05$) reduced with increased in cooking temperature. The differences in Fe content caused by cooking temperatures were significant ($p< 0.05$). Cooking at 170℃ resulted to significantly ($p < 0.05$) higher Fe content than cooking at 180℃ and 190℃. The lower Fe content of cooked samples could be attributed to denaturation of myoglobin molecules. The findings are in line with reported results by Lombardi-Boccia et al. [4] who stated that heat treatments were not responsible for losses in total iron concentration, but it altered the heme: non-heme ratio, as well as caused reduction in the heme iron concentration content.

The reduction of Fe content with increasing temperature could be attributed to alteration the heme: non-heme ratio and reduction in the heme iron concentration content. The interaction between cooking methods and temperatures was significant ($p < 0.05$), suggesting that the differences in Fe content caused by the temperature were different at different cooking temperature. It could be deduced from Table 6 that the differences in Fe content between AF and BK (AF – BK), between AF and DF (AF – DF), between BK and DF (BK – DF) and between BK and GR (BK –GR) of cooked samples decreased with increased in cooking temperatures. On the other hand, the differences in Fe content between AF and GR (AF– GR) or between DF and GR (DF – GR) were neither increasing nor decreasing with increase in cooking temperatures. From this interaction, it is deduced that AF method resulted to least Fe content each cooking temperature compared to other cooking methods, with the AF method producing the least Fe content at 190℃ cooking temperature. This may suggest that, modification the heme: non-heme ratio and lessening in the heme iron concentration content was higher at higher temperatures. Although all products continued to reduce in Fe content as temperature of cooking increased, the baked (BK) products had the highest Fe content at 170℃ and 180℃ cooking temperature, while deep fat fried (DF) had the highest Fe content at 190℃, suggesting that there was less heme: non-heme ratio modification and lessening in the heme iron concentration content.

The results in Table 6 showed that cooking time affected Fe content. The average Fe contents at 4, 8 and 12 min were12.24 mg/Kg, 11.47 mg/Kg, and 10.83 mg/Kg, respectively. Thus Fe 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 significant ($p < 0.05$), suggesting that the Fe content due to the cooking methods were different at different cooking times. The significant interaction ($p < 0.05$) showed that the differences in Fe content between BK and DF (BK – DF) were increasing with increase cooking times, while the differences in Fe content between AF and BK (AF - BK), AF and DF (AF – DF), AF and GR (AF – GR), BK and GR (BK –GR) were decreasing with increase in cooking times, but the differences in Fe content between 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 significant ($p < 0.05$). This Suggests that the differences in Fe content 170 and 180°C (170 - 180°C) and 170 and 190°C (170 - 190°C) were decreasing with increase in cooking times. On the other hand, the differences in Fe content between 180 and 190°C (180 - 190°C) were similar at each cooking time. However, the overall interaction (Method x Temperature x Time) was not found to be significant. The Fe coefficient of determination R^2 is 95.7%. This value is very high, indicating treatment variables and their interactions affected the observed decreases in Fe content.

Table 7 showed the Zn content of chicken breast meat. Cooking methods significantly ($p < 0.05$) affected Zn content. It was observed in Table 7 that samples cooked by air frying (AF) had an average Zn content of 26.48 mg/Kg, samples cooked by baking (BK) had 29.38 mg/Kg, deep fat frying (DF) had 26.43 mg/Kg, while grilling (GR) had mean Zn content of 39.06 mg/Kg. The differences in Zn content due to cooking methods were significant ($p < 0.05$). The lower Zn content of cooked samples could be attributed to oxidation of denatured proteins and bonded Zn content. Cooking decreased significantly ($p < 0.05$) Zn content of cooked chicken breast meat samples with increasing cooking time and cooking temperature. Similar finding has been reported by Oz et al. [23] in beef steaks. Equally, Erosy and Ozeren [20] reported that only GR method had a significant effect on Zn content of African catfish.

Cooking temperature significantly ($p < 0.05$) affected Zn content of cooked chicken breast meat. The average Zn contents in the samples cooked at 170, 180 and 190℃ were 31.75 mg/Kg, 30.20 mg/Kg and 29.07 mg/Kg, respectively. Thus, Zn content significantly ($p < 0.05$) reduced with increased in cooking temperature. The differences in Zn content caused by cooking temperatures were significant ($p< 0.05$). Cooking at 170℃ resulted to significantly ($p < 0.05$) higher Zn content than cooking at 180℃ and 190℃. The lower Zn content of cooked samples could be attributed to oxidation of denatured proteins and Zn content. The reduction of Zn content with increasing temperature could be attributed to oxidation of Zn content bonded to denatured proteins. The interaction between cooking methods and temperatures was significant ($p < 0.05$),

suggesting that the differences in Zn content caused by the temperature were different at different cooking temperature. It could be deduced from Table 7 that the differences in Zn content between BK and DF (BK – DF) were increasing with increase cooking temperatures, whereas the differences in Zn content between AF and BK (AF – BK) were decreasing with increase cooking temperatures. The differences in Zn content between AF and GR (AF – GR) were similar at each cooking temperature. On the other hand, the differences in Zn content between AF and DF (AF – DF) or BK and GR (BK –GR) or DF and GR (DF – GR) were neither increasing nor decreasing with increase cooking temperatures. It is deduced from interaction that AF cooked samples had the least Zn content at 170°C, whereas DF cooked samples at 180°C and 190 °C compared to other cooking methods. The lower mean Zn content of DF cooked samples could be attributed to stripping actions of Zn on cooking samples by the cooking oil. Although all products continued to reduce in Zn content as temperature of cooking increased, the grilled (GR) products had the highest Zn content at each cooking temperature, suggesting that there was less oxidation and drip losses of Zn content. The results in Table 7showed that cooking time affected Zn content. The average Zn contents at 4, 8 and 12 min were 30.74 mg/Kg, 29.23 mg/Kg, and 28.81mg/Kg, respectively. Thus Zn 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 significant ($p < 0.05$). This suggests that the Zn content due to the cooking methods were different at different cooking times. The significant interaction ($p < 0.05$) showed that the differences in Zn content between AF and GR (AF – GR), BK and DF (BK – DF) and DF and GR (DF – GR), were increasing with increase cooking times, while the differences in Zn content between AF and BK (AF - BK) or between AF and DF (AF – DF) or between BK and GR (BK – GR), respectively were neither increasing nor decreasing with increase in cooking times. The results showed that the interaction between cooking temperatures and cooking times was significant ($p < 0.05$), suggesting that the differences in Zn content between 170 and 180°C (170 - 180°C), 170 and 190°C (170 - 190°C) and 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 confirm why the products fried with vegetable oil (DF) at 190℃ for 12 min had the least Zn content (20.59 mg/Kg), while the products obtained by grilled (GR) at 170℃ for 4 min had the highest Zn content (41.66 mg/Kg). The Zn coefficient of determination R^2 is 99.7 %. This value is very high, indicating treatment variables and their interactions affected the observed decreases in Zn content.

3.2 Changes in Vitamin Contents

3.2.1 Changes in vitamin contents of chicken breast meat

The results of vitamins B_1, B_2, B_3, B_6, B_9, B_{12} and C contents of chicken breast meat cooked at different methods each at 170, 180 and 190 ^{0}C for 0, 8 and 16 min are shown in Tables 8, 9, 10, 11, 12,13 and 14, respectively. The results in Tables 8, 9, 10, 11, 12, 13 and 14 showed that cooking reduced the vitamins B_1, B_2, B_3, B_6, B_9, B_{12} and C contents. On the average, vitamins B_1, B_2, B_3, B6, B_9, B_{12} and C contents reduced to an overall mean values of 0.028, 0.067, 0.026, 0.205, 0.116, 0.108 and 0.103 mg/100 g, respectively.

Cooking methods significantly ($p < 0.05$) affected vitamin B_1 content. The results in Table 8 showed that samples cooked by air frying (AF) had an average vitamin B_1 content of 0.027 mg/100 g, while samples cooked by baking (BK) had 0.031 mg/100 g, deep fat frying (DF) had 0.022 mg/100 g and grilling (GR) had mean vitamin B_1content of 0.030 mg/100 g. The differences in vitamin B_1 content due to cooking methods were significant ($p < 0.05$) and BK cooked samples had significantly ($p <0.05$) higher vitamin B_1 content except with GR cooked samples. The lower vitamin B_1 content of DF compared to others could be attributed to leaching effect of vitamin B_1 into the cooking oil Most of vitamin B_1 content of deep fat fried samples was lost by stripping or leaching out into the frying oil as reported by Leskova et al. (2006).These results are in line with reported findings by Lynch and Young [24] and Bakhru [25] who reported thermal reduction and vitamin B_1 losses by cooking.

Table 1. Calcium (mg/Kg) of chicken breast at different cooking method, temperature and time

Cooking	Cooking	Cooking time min				Mean cooking	
Method	**temp.℃**	**0**	**4**	**8**	**12**	**temp ℃**	**Method**
AF	170	300.27± 4.24	174.63 ±3.75	154.00 ±5.44	138.50 ± 2.76	191.35	
	180	300.27± 4.24	168.30 ± 2.57	133.67 ± 3.53	116.24 ± 0.20	179.73	
	190	300.27± 4.24	153.71 ± 0.80	116.47 ±0.71	108.47 ±3.30	169.73	
Mean		300.27 ± 3.28	165.55 ± 10.07	134.71± 17.06	120.40± 13.09	180.23	180.23 ^{c}±10.82
BK	170	300.27± 4.24	221.38 ± 3.82	171.68± 1.07	156.72± 1.36	212.52	
	180	300.27± 4.24	210.06 ±7.61	164.75±0.00	148.35 ± 3.28	205.86	
	190	300.27± 4.24	185.31 ± 6.10	157.17 ± 3.78	129.75 ± 0.01	193.12	
Mean		300.27 ± 3.28	205.58 ± 17.15	164.53 ± 6.73	144.94 ±12.45	203.83	203.83 ^{b}±9.82
DF	170	300.27± 4.24	161.81 ± 5.03	138.11 ± 3.44	98.96 ± 4.77	174.79	
	180	300.27± 4.24	150.44 ± 3.25	124.17 ± 3.42	87.19 ±4.77	165.52	
	190	300.27± 4.24	132.49 ± 2.33	110.73 ± 2.33	75.07 ± 1.03	154.64	
Mean		300.27 ± 3.28	148.25 ± 13.53	124.34± 12.48	87.07 ± 10.94	164.98	164.98 ^{d}±10.09
GR	170	300.27± 4.24	237.66± 4.21	220.68 ± 2.38	210.48± 1.53	242.27	
	180	300.27± 4.24	229.08 ± 2.45	216.03 ± 2.74	188.02 ± 3.31	233.35	
	190	300.27± 4.24	223.66 ± 4.32	195.83 ±7.25	121.46 6.96	210.30	
Mean		300.27 ± 3.28	230.13 ± 6.95	210.84± 12.36	173.32 ± 41.56	228.64	228.64 ^{a}±16.50
Grand mean		**300.27 ^{a} ± 3.06**	**187.38 ^{b} ± 34.98**	**158.60 ^{c} ±36.28**	**131.43 ^{d} ±39.02**		**194.42±27.85**

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. Potassium (mg/Kg) of chicken breast at different cooking method, temperature and time

Cooking	Cooking	Cooking time (min)				Mean cooking
Method	temp.℃	0	4	8	12	Method
AF	170	16673.13± 29.17	14350.41 ±53.55	14341.27 ± 78.94	13691.87 ± 143.43	
	180	16673.13± 29.17	14199.00 ± 127.49	13930.36 ± 78.65	12466.12 ± 114.04	
	190	16673.13± 29.17	13663.61 ± 80.16	13492.91 ± 140.44	12302.57 ± 35.28	
Mean		16673.13 ± 22.59	14071.01±330.57	13921.52 ±387.84	12820.19 ± 434.26	14371.46^{c}
BK	170	16673.13± 29.17	14905.19 ± 72.49	14093.19± 78.86	13361.62 ± 124.78	
	180	16673.13± 29.17	14123.29 ± 93.59	13662.67 ± 162.51	12825.62 ± 124.13	
	190	16673.13± 29.17	14048.90 ± 34.94	13655.81 ± 11.17	12502.14 ± 137.69	
Mean		16673.13±22.59	14359.13 ± 427.86	13803.89 ±238.35	12896.46 ±400.93	14433.15^{b}
DF	170	16673.13± 29.17	14187.00 ± 43.98	13836.06 ± 127.43	13774.11 ± 14.99	
	180	16673.13± 29.17	14036.96 ± 16.06	13644.13 ± 95.54	13344.45 ±63.11	
	190	16673.13± 29.17	13875.74 ± 98.17	13257.70 ± 122.68	12989.58 ± 45.92	
Mean		16673.13 ± 22.59	14033.24 ± 147.48	13579.30 ±]278.40	13369.38 ± 353.18	14413.76^{bc}
GR	170	16673.13± 29.17	14880.79± 67.87	14199.60 ± 109.29	13478.28 ± 69.25	
	180	16673.13± 29.17	14587.60 ± 46.15	14029.19 ± 39.77	13449.65 ± 84.42	
	190	16673.13± 29.17	14214.01±82.59	13308.77 ± 99.13	12903.79 ± 112.11	
Mean		16673.13 ± 22.59	14560.80 ±342.56	13845.85± 211.80	13277.24 ± 191.80	14589.26^{a}
Grand mean		**16673.13 ^{a}± 21.07**	**14256.04 ^{b} ± 370.37**	**13787.64 ^{c} ±344.61**	**13090.82 ^{d}± 497.52**	**14451.91**

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 3. Magnesium (mg/Kg) of chicken breast at different cooking method, temperature and time

Cooking	Cooking	Cooking time (min)				Mean cooking	
Method	**temp.^{0}C**	**0**	**4**	**8**	**12**	**temp ℃**	**Method**
AF	170	1336.37 ± 63.93	1358.49 ± 5.32	1372.06 ± 10.15	1382.21± 12.23	1362.28	
	180	1336.37 ± 63.93	1372.89± 17.52	1389.34 ± 6.99	1430.55 ± 1.34	1382.28	
	190	1336.37 ± 63.93	1543.21±13.54	1603.73± 18.50	1659.50 ± 28.50	1535.70	
Mean		1336.37 ± 49.52	1424.86 ± 92.46	1455.04± 115.86	1490.75 ± 133.21	1426.75	1426.75 ^{c}±112.15
BK	170	1336.37 ± 63.93	1381.73 ± 25.72	1604.24 ± 2.23	1627.01± 21.85	1487.33	
	180	1336.37 ± 63.93	1455.54 ± 11.26	1566.16 ± 4.85	1652.43 ± 4.53	1502.62	
	190	1336.37 ± 63.93	1525.77 ± 3.52	1662.31 ±5.23	1696.19 ± 10.94	1555.15	
Mean		1336.37 ± 49.52	1454.35 ± 65.66	1610.90 ± 43.44	1658.53 ± 33.11	1515.04	1515.04 ^{b}± 138.48
DF	170	1336.37 ± 63.93	1531.33 ± 1.77	1567.87 ± 5.11	1601.75 ± 15.46	1509.33	
	180	1336.37 ± 63.93	1564.96 ± 19.35	1594.63 ±5.40	1641.49 ± 0.00	1534.36	
	190	1336.37 ± 63.93	1606.79 ± 26.34	1645.45 ± 20.15	1667.32 ±6.92	1563.99	
Mean		1336.37 ± 49.52	1567.69 ± 36.85	1602.65 ± 36.53	1636.85 ± 30.50	1535.89	1535.89 ^{a}± 125.66
GR	170	1336.37 ± 63.93	1382.39 ± 11.64	1525.22 ± 15.32	1533.52± 11.40	1444.37	
	180	1336.37 ± 63.93	1491.56 ±15.68	1581.66 ±13.94	1664.04 ±8.99	1518.40	
	190	1336.37 ± 63.93	1616.59 ±3.63	1645.52 ± 29.39	1667.08 ± 4.70	1566.39	
Mean		1336.37 ± 49.52	1496.15 ± 105.19	1584.13 ± 56.18	1621.55 ± 68.54	1509.72	1509.72 ^{b}±131.28
Grand mean		**1336.37^{d} ± 46.18**	**1485.94 ^{c} ± 92.03**	**1563.18^{b}± 92.03**	**1601.92 ^{a} ± 98.99**	**1496.85**	**1496.85±48.08**

Data are means of duplicate determinations ± standard deviations
Values with different superscripts row- wise and column- wise differ significantly ($p < 0.05$)
AF air frying
BK baking
DF deep fat frying
GR grilling

Table 4. Phosphorus (mg/Kg) of chicken breast meat at different cooking method, temperature and time

Cooking	Cooking	Cooking time (min)				Mean cooking	
Method	temp. ^{0}C	0	4	8	12	temp ℃	Method
AF	170	8995.00 ±124.45	8259.00±74.95	7856.50 ± 82.73	7736.50±21.92	8211.75	
	180	8995.00 ±124.45	8160.00 ±73.54	7617.50 ±118.09	7608.00± 57.98	811O.13	
	190	8995.00 ± 124.45	7369.50 ± 57.28	7345.50 ± 6.36	7333.00 ± 28.28	7760.75	
Mean		8995.00 ± 96.40	7929.50 ± 279.30	7626.50 ± 240.73	7559.17 ± 186.87	8027.54	8027.54^{a} ± 236.57
BK	170	8995.00 ±124.45	8256.00 ±43.84	7720.50 ± 30.41	7587.50 ± 47.38	8139.75	
	180	8995.00±124.45	7973.50± 6.36	7622.00± 98.99	7499.50 ± 2.12	8022.50	
	190	8995.00 ±124.45	7684.50 ± 77.07	7258.50 ± 70.00	7244.00 ± 29.70	7795.50	
Mean		8995.00 ± 96.40	7971.33 ±258.66	7533.67± 224.71	744367±161.54	7985.92	7985.92^{a} ± 175.02
DF	170	8995.00 ±124.45	7641.50±60.10	7479.00 ±87.68	7326.50±30.41	7860.50	
	180	8995.00 ±124.45	7569.50± 34.65	7391.50 ± 98.29	7275.00± 33.94	7807.75	
	190	8995.00 ±124.45	7465.50 ± 63.64	7384.50 ± 38.89	7066.50 ± 31.82	7727.75	
Mean		8995.00 ±96.40	7558.67± 89.85	7418.33 ±77.40	7222.67 ±125.62	7798.67	7798.67^{b} ± 66.84
GR	170	8995.00 ±124.45	7720.00 ± 45.25	7523.50 ± 10.61	7273.50± 36.06	7878.00	
	180	8995.00 ±124.45	7516.00 ± 67.88	7415.00 ± 22.63	7105.00 ± 33.94	7757.75	
	190	8995.00 ±124.45	7416.00 ± 26.87	7312.50 ± 65.76	7005.50 ± 48.79	7682.25	
Mean		8995.00 ±96.40	7550.67±143.80	7417.00 ±99.48	7128.00 ± 125.10	7772.67	7772.67^{b} ± 98.72
Grand mean		**8995.00^{a} ± 0.00**	**7752.54^{b} ±326.82**	**7498.88^{c} ± 184.09**	**7338.38^{d}± 228.77**	**7896.20**	**7896.20 ±129.14**

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. Sodium (mg/Kg) of chicken breast meat at different cooking method, temperature and time

Cooking	Cooking	Cooking time (min)				Mean cooking	
Method	Temp ^{0}C	0	4	8	12	Temp℃	Method
	170	2863.82±25.51	2515.31 ± 6.96	2374.23 ± 16.01	1822.05 ± 8.69	2393.85	
AF	180	2863.82±25.51	2256.26 ±11.96	1832.88 ± 12.61	1490.09 ± 7.47	2110.76	
	190	2863.82±25.51	1441.23 ± 29.59	1359.24 ± 28.88	1278.69 ± 5.81	1735.74	
Mean		2863.82±19.76	2070.93 ±201.53	1855.40 ± 254.35	1530.27 ± 245.05	2080.12	2080.12 ^{c}±330.12
BK	170	2863.82±25.51	2643.33 ± 10.74	2325.20 ± 12.05	2185.50 ± 19.94	2501.42	
	180	2863.82±25.51	2541.32 ± 11.39	2142.39 ± 11.14	2123.90 ± 5.58	2417.39	
	190	2863.82±25.51	2386.16 ± 7.69	2079.11 ± 16.65	1370.48 ± 5.60	2174.89	
Mean		2863.82 ±19.76	2523.60 ±116.09	2182.23±114.78	1893.29 ±206.62	2365.74	2365.74^{b}± 169.55
DF	170	2863.82±25.51	2178.68 ± 24.81	1875.34 ± 10.94	1748.37 ± 9.10	2166.55	
	180	2863.82±25.51	1959.87 ± 12.99	1755.52 ± 0.00	1670.61 ± 10.94	2089.95	
	190	2863.82±25.51	1881.82 ± 43.61	1648.33 ± 14.02	1523.77 ± 14.97	2011.93	
Mean		2863.82 ±19.76	2006.79 ± 139.58	1759.73 ± 48.42	1647.58 ± 102.43	2069.48	2069.48^{c}± 77.31
GR	170	2863.82±25.51	2809.21 ± 14.62	2504.28 ± 10.79	2225.22 ± 23.33	2600.63	
	180	2863.82±25.51	2761.55 ± 9.57	2399.83 ± 10.71	1978.65 ± 9.57	2500.96	
	190	2863.82±25.51	2661.55 ± 16.91	2006.12 ± 9.38	1819.11 ± 14.30	2337.65	
Mean		2863.82 ±19.76	2744.10 ± 68.29	2303.41 ±135.10	2007.66 ±183.46	2479.75	2479.75^{a}± 132.77
Grand mean		**2863.82 ^{a}±18.43**	**2336.35 ^{b}± 402.61**	**2025.20 ^{c}± 320.94**	**1769.70 ^{d}± 309.98**	**2248.77**	**2248.77 ±206.25**

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. Iron (mg/Kg) of chicken breast meat at different cooking method, temperature and time

Cooking	Cooking	Cooking time (min)				Mean cooking	
Method	Temp ^{0}C	0	4	8	12	Temp℃	Method
AF	170	15.15 ± 0.73	12.07 ± 0.44	11.09 ± 0.43	10.60 ± 0.66	12.23±1.94	
	180	15.15 ± 0.73	10.82 ± 0.57	10.60 ± 0.28	10.25 ± 0.03	11.71±2.17	
	190	15.15 ± 0.73	10.53 ± 0.11	10.40 ± 0.08	10.12 ± 0.06	11.55±2.24	
Mean		15.15 ± 0.57	11.14±0.80	10.70 ± 0.39	10.32±0.37	11.83 ± 2.05	11.83 ^{c} ±2.05
BK	170	15.15 ± 0.73	14.69 ± 0.15	14.35 ± 0.07	12.95 ± 0.65	14.28±0.96	
	180	15.15 ± 0.73	12.50 ± 0.33	12.06 ± 0.44	12.03 ±0.45	12.93±1.43	
	190	15.15 ± 0.73	11.19 ± 1.03	10.23 ± 0.11	10.02 ± 0.01	11.65±2.26	
Mean		15.15 ± 0.57	12.80 ±1.65	12.21±1.87	11.66 ±1.39	12.95 ±1.92	12.95 ^{a}±1.92
DF	170	15.15 ± 0.73	14.02 ± 0.95	13.00 ± 0.47	12.21 ± 0.10	13.59±1.27	
	180	15.15 ± 0.73	12.23 ± 0.11	11.55± 0.73	10.51 ± 0.71	12.36±1.90	
	190	15.15 ± 0.73	11.61 ± 1.12	11.19 ± 1.03	10.22 ± 0.11	12.04±2.09	
Mean		15.15 ± 0.57	12.62 ± 1.30	11.91±1.05	10.98 ±1.01	12.67±1.84	12.67 ^{a} ± 1.84
GR	170	15.15 ± 0.73	13.83 ±0.36	11.15 ± 0.20	10.59 ± 0.59	12.68±2.05	
	180	15.15 ± 0.73	12.16 ±0.04	11.77 ± 0.55	10.26 ± 0.12	12.34±1.92	
	190	15.15 ± 0.73	11.16 ± 0.87	10.25 ± 0.03	10.21 ± 0.01	11.69±2.21	
Mean		15.15 ± 0.57	13.65± 1.12	12.40 ±1.48	11.59 ±1.17	13.20±1.74	12.24 ^{b} ± 2.02
Grand mean		**15.15 ^{a} ± 0.53**	**12.24 ^{b}± 1.38**	**11.47 ^{c}±1.24**	**10.83 ^{d}± 1.00**	**12.42 ± 1.97**	**12.42 ±0.49**

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. Zinc (mg/Kg) of chicken breast meat at different cooking method, temperature and time

Cooking	Cooking	Cooking time (min)				Mean cooking	
Method	temp.^{0}C	0	4	8	12	temp ℃	Method
AF	170	32.57 ± 0.27	28.51 ± 0.69	24.54 ± 0.69	23.99 ± 0.47	27.40± 3.72	
	180	32.57 ± 0.27	25.83 ± 0.56	24.69 ± 0.62	22.58 ± 0.68	26.42±4.02	
	190	32.57 ± 0.27	24.66 ± 0.63	23.98 ± 0.48	21.30 ±0.14	25.63±4.50	
Mean		32.57 ± 0.21	26.33 ±1.83	24.40 ±0.57	22.62 ±1.26	26.48 ±3.98	26.48 ^{c} ± 0.89
BK	170	32.57 ± 0.27	31.68 ± 62	29.77 ± 0.77	28.09 ± 0.17	30.53±1.90	
	180	32.57 ± 0.27	30. 73 ± 0.59	27.56 ± 0.68	26.65 ± 0.64	29.38±2.59	
	190	32.57 ± 0.27	28.08 ± 0.98	26.25 ±0.35	25.99 ± 0.47	28.22±2.85	
Mean		32.57 ± 0.21	30.16 ±1.77	27.86 ±1.67	26.91 ±1.03	29.38 ±2.56	29.38 ^{b} ± 1.16
DF	170	32.57 ± 0.27	29.21 ± 0.37	26.23 ± 0.36	25.55 ± 0.68	28.39±2.99	
	180	32.57 ± 0.27	25.39 ±0.71	24.78 ± 0.58	22.61 ± 0.66	26.34±4.03	
	190	32.57 ± 0.27	24.23 ± 0.11	20.89 ± 0.52	20.59 ± 0.67	24.57±5.18	
Mean		32.57 ± 0.21	26.27± 2.36	23.97±2.50	22.91±2.29	26.43±4.29	26.43 ^{c} ± 1.91
GR	170	32.57 ± 0.27	41.66 ± 0.63	42.58 ± 0.66	45.82 ±0.55	40.66±5.22	
	180	32.57 ± 0.27	39 89 ± 0.48	40.13 ± 0.22	42. 06 ± 0.45	38.66±3.87	
	190	32.57 ± 0.27	38.99 ± 0.48	39.43 ± 0.21	40.48 ± 0.79	37.87±3.36	
Mean		32.57 ± 0.21	40.18 ±1.28	40.71 ±1.52	42.78 ±2.53	39.06±4.23	39.06 ^{a} ± 1.44
Grand Mean		**32.57 ^{a} ± 0.19**	**30.74 ^{b}± 6.05**	**29.23 ^{c}± 7.12**	**28.81 ^{d}± 8.61**	**30.34 ± 6.42**	**30.34±5.98**

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 temperature significantly ($p < 0.05$) affected vitamin B_1 content of cooked chicken breast meat. The average vitamin B_1 contents on cooking samples at 170, 180 and 190^{0}C were 0.031 mg/100 g, 0.026 mg/100 g and 0.025 mg/100 g, respectively. Thus, vitamin B_1 content significantly ($p < 0.05$) reduced with increase in cooking temperatures. The differences in vitamin B_1 content caused by cooking temperatures were significant ($p< 0.05$). Cooking at 170^{0}C resulted to significantly ($p < 0.05$) higher vitamin B_1 content than cooking at 180^{0}C and 190^{0}C. The reduction of vitamin B_1 content with increasing cooking temperature could be attributed to thermal reduction. The interaction between cooking methods and temperatures was significant ($p < 0.05$), suggesting that the differences in vitamin B_1 content caused by the cooking methods were different at different temperatures. From this interaction, it is deduced that DF method resulted to least vitamin B_1 content at each cooking temperature compared to other cooking methods. This may suggest that, in addition to moisture loss, more thiamine content were lost. The reduction could be attributed to thermal degradation of thiamine. This finding agrees with Al-Khalifa and Dawood [26], Pathare and Roskilly [27] and Alugwu and Alugwu [28] who reported that thiamine was sensitive to heat and higher losses of thiamine occurred during roasting and deep-fat frying of chicken meat. Although all products continued to reduce in thiamine content as temperature of cooking increased, the baked (BK) products had the highest thiamine content at each cooking temperature, suggesting that there was less loss of vitamin B_1 at each temperature compared with other cooking methods.

The results in Table 8 showed that cooking time affected vitamin B_1 content. The average vitamin B_1 contents at 8 and 16 min were 0.022 mg/100g and 0.012 mg/100g. Thus vitamin B_1 content significantly ($p < 0.05$) reduced as cooking time increased. The differences are attributed to long time exposure 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 vitamin B_1 content due to the cooking methods were different at different cooking times. The significant interaction ($p < 0.05$) showed that the differences in vitamin B_1 content between AF and BK (AF - BK) and BK and GR (BK - GR) were increasing with increase in cooking times, but the differences in vitamin B_1 content between AF and DF (AF - DF), AF and GR (AF – GR), BK and DF (BK - DF) and DF and GR (DF and GR) were decreasing with increase in cooking times. The interaction between cooking temperatures and cooking times was significant ($p < 0.05$). This suggests that the differences in vitamin B_1 content between 170 and 180^{0}C (170 - 180^{0}C), 170 and 190^{0}C (170 - 190^{0}C) and180 and 190^{0}C (180 - 190^{0}C) were decreasing with increase cooking times. However, the overall interaction (Method x Temperature x Time) was found to be significant. This significant ($p < 0.05$) overall interaction confirmed why the products deep fat fried (DF) at 190^{0}C for 16 min had the least vitamin B_1 content (0.006 mg/100 g), while the products obtained by grilling (GR) at 170^{0}C for 8 min had the highest vitamin B_1 content (0.039 mg/100 g). The B_1 coefficient of determination R^2 is 99.6 %. This value is very high, indicating treatment variables and their interactions affected the observed decreases in vitamin B_1 content.

The results in Table 9 showed that cooking reduced the vitamin B_2 content of chicken breast meat treated with different cooking methods. On the average, vitamin B_2 content reduced to an overall mean of 0.067 mg/100 g. The reduction in vitamin B_2 content of chicken breast meat treated with different cooking methods could be attributed to thermal denaturation of proteins and leaching out of the vitamin.

Cooking methods significantly ($p < 0.05$) affected vitamin B_2 content. It was observed in Table 9 that samples cooked by air frying (AF) had an average vitamin B_2 content of 0.071 mg/100 g, samples cooked by baking (BK) had 0.068 mg/100 g, deep fat frying (DF) had 0.061 mg/100 g, while grilling (GR) had mean vitamin B_2 content of 0.067 mg/100 g. The differences in vitamin B_2 content due to cooking methods were significant ($p < 0.05$) and samples cooked by AF had significantly ($p <0.05$) higher vitamin B_2 content than others. Vitamin B_2 is stable to heat and oxidation, but reduced by light as reported by Leskova et al. (2006) and Gerber et al. [29]. The differences in vitamin B_2 content due to cooking methods were significant ($p < 0.05$) and samples cooked by AF had significantly ($p <0.05$) higher vitamin B_2 content than others. The lower vitamin B_2 content of DF compared to others could be attributed to thermal denaturation and stripping action of vitamin B_2 from the substrates into the frying oil.

Cooking temperature significantly ($p < 0.05$) affected vitamin B_2 content of cooked chicken

breast meat. Cooking at 170^{0}C gave average vitamin B_2 content of 0.073 mg/100 g, at 180 °C average vitamin B_2 content was 0.067 mg/100 g and at 190 ^{0}C, average vitamin B_2 content was 0.060 mg/100 g. Thus, vitamin B_2 content significantly ($p < 0.05$) reduced with increase in cooking temperature. The differences in vitamin B_2 content caused by cooking temperatures were significant ($p< 0.05$). Cooking at 170^{0}C resulted to significantly ($p < 0.05$) higher vitamin B_2 content than cooking at 180^{0}C and 190^{0}C. The reduction of vitamin B_2 content with increasing temperature could be attributed to thermal degradation by heat. The results are in accordance with similar research conducted by Al-Khalifa and Dawood [26] and Lombardi – Boccia et al. (2005), where vitamin B_2 content had higher retention values that ranged from 20 – 58 % after cooking and more stable to heat. The interaction between cooking methods and temperatures was not significant ($p > 0.05$), suggesting that the differences in vitamin B_2 content caused by the cooking methods were similar at each cooking temperature.

The results in Table 9 showed that cooking time affected vitamin B_2 content. The average vitamin B_2 contents at 8 and 16 min were 0.061 mg/100 g and 0.043 mg/100 g. Thus vitamin B_2 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 ($p < 0.05$). This suggests that the vitamin B_2 content due to the cooking methods were different at different cooking times. The significant interaction ($p < 0.05$) showed that the differences in vitamin B_2 content between AF and BK (AF - BK), AF and DF (AF - DF), BK and DF (BK - DF) and DF and GR (DF - GR) were decreasing with increase in cooking times, but the differences in vitamin B_2 content between AF and GR (AF - GR) and between BK and GR (BK - GR) were increasing 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 vitamin B_2 content between170. and 180^{0}C (170 - 180^{0}C) were increasing with increase in cooking times. On the other hand, the differences in vitamin B_2 between 170 and 190^{0}C (170 - 190^{0}C) and between180 and 190^{0}C (180 - 190^{0}C) were decreasing with increase in cooking times. However, the overall interaction (Method x Temperature x Time) was not found to be significant ($p > 0.05$). The vitamin B_2 coefficient of determination R^2 is 98.6 %. This value is very high, indicating treatment variables and their interactions affected the observed decreases in vitamin B_2 content.

The results in Table 10 showed that cooking reduced the vitamin B_3 (Niacin) content of chicken breast meat. On the average, vitamin B_3 content reduced to an overall mean of 0.026 mg/100 g. The reduction in vitamin B_3 content of chicken breast meat treated with different cooking temperature, suggesting that there was less stripping of vitamin B_3 content and drip loss at each temperature compared with other cooking methods.

The results in Table 10 showed that cooking time affected vitamin B_3 content. The average vitamin B_3 contents at 8 and 16 min were 0.023 mg/100 g and 0.018 mg/100 g, respectively. Thus vitamin B_3 content significantly ($p < 0.05$) reduced as cooking time increased. This finding agrees with reported findings by Lynch and Young [24] and Murphy and Marks [30] who observed that increased reduction of vitamin B_3 content with increasing cooking temperature and time. The differences are attributed to long time exposure 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 vitamin B_3 content due to the cooking methods were different at different cooking times. The significant interaction ($p < 0.05$) showed that the differences in vitamin B_3 content between AF and DF (AF - DF) and BK and GR (BK – GR) were increasing with increase in cooking times, while differences in vitamin B_3 content between AF and BK (AF - BK), AF and GR (AF – GR), BK and DF (BK - DF), DF and GR (DF - GR) were decreasing with increase in cooking times. The significant interaction ($p < 0.05$) between cooking temperatures and cooking times showed that the differences in vitamin B_3 content 170 and 180^{0}C (170 - 180^{0}C) and 170 and 190^{0}C (170 - 190^{0}C) were decreasing with increase cooking times. Whereas the differences in vitamin B_3 content between180 and 190^{0}C (180 - 190^{0}C) were increasing with increase in cooking times. However, the overall interaction (Method x Temperature x Time) was not found to be significant. The coefficient of determination R^2 is 99.3%. This value is very high, indicating treatment variables and their interactions affected the observed decreases in vitamin B_3 content.

Table 8. Vitamin B_1 (mg/100 g) of chicken breast at different cooking method, temperature and time

Cooking	Cooking	Cooking time (min)			Meaning cooking	
Method	**Temp^{0}C**	**0**	**8**	**16**	**Temp ℃**	**Method**
AF	170	0.049 ± 0.01	0.035 ± 0.00	0.011 ±0.000	0.032 ± 0.017	
	180	0.049 ± 0.01	0.019 ±0.004	0.010 ± 0.002	0.026 ± 0.018	
	190	0.049 ± 0.01	0.012 ± 0.002	0.009 ± 0.001	0.023 ± 0.020	
Mean		0.049 ± 0.01	0.022 ± 0.011	0.010 ± 0.002	0.027 ± 0.005	0.027 ^{b} ± 0.005
BK	170	0.049 ± 0.01	0.030 ± 0.001	0.025 ± 0.000	0.034 ± 0.011	
	180	0.049 ± 0.01	0.025 ± 0.000	0.019 ± 0.001	0.031 ± 0.014	
	190	0.049 ± 0.01	0.021 ± 0.001	0.014 ± 0.001	0.028 ± 0.012	
Mean		0.049 ± 0.01	0.025 ±0.004	0.019 ± 0.005	0.031 ± 0.003	0.031^a ± 0.003
DF	170	0.049 ± 0.01	0.014 ± 0.002	0.008 ± 0.001	0.023 ± 0.020	
	180	0.049 ± 0.01	0.011 ± 0.001	0.007 ± 0.001	0.022 ± 0.021	
	190	0.049 ± 0.01	0.008 ± 0.001	0.006 ± 0.001	0.021 ± 0.022	
Mean		0.049 ± 0.01	0.011 ± 0.003	0.007 ± 0.001	0.022 ± 0.001	0.022^c ± 0.001
GR	170	0.049 ± 0.01	0.039 ± 0.001	0.016 ± 0.000	0.034 ± 0.015	
	180	0.049 ± 0.01	0.035 ± 0.000	0.009 ± 0.004	0.031 ±0.018	
	190	0.049 ± 0.01	0.023 ± 0.002	0.007 ± 0.002	0.026 ± 0.019	
Mean		0.049 ± 0.01	0.032 ± 0.008	0.011 ± 0.005	0.030 ± 0.004	0.030^a ± 0.004
Grand mean		**0.049 ^{a} ± 0.001**	**0.022^b ± 0.010**	**0.012^c ± 0.006**	**0.027 ± 0.017**	**0.028 ±0.004**

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 9. Vitamin B_2 (mg/100 g) of chicken breast at different cooking method, temperature and time

Cooking	Cooking time (min)			Mean cooking	
Temp ^{0}C	**0**	**8**	**16**	**temp ℃**	**Method**
170	0.097 ± 0.005	0.079 ± 0.000	0.063 ± 0.002	0.079 ± 0.026	
180	0.097 ±0.005	0.071 ±0.000	0.042 ± 0.001	0.070 ± 0.025	
190	0.097 ±0.005	0.059 ± 0.00	0.040 ± 0.002	0.065 ± 0.025	
	0.097 ±0.005	0.070 ± 0.004	0.048 ± 0.011	0.071 ± 0.022	0.071 ^{a} ± 0.007
170	0.097 ±0.005	0.070 ± 0.004	0.059 ± 0.004	0.075 ± 0.018	
180	0.097 ±0.005	0.062 ± 0.010	0.044 ± 0.008	0.067 ± 0.025	
190	0.097 ±0.005	0.047 ± 0.004	0.040 ± 0.004	0.061 ± 0.028	
	0.097 ±0.005	0.060 ± 0.011	0.047± 0.010	0.068 ± 0.023	0.068 ^{b}± 0.023
170	0.097 ±0.005	0.055 ± 0.000	0.043 ± 0.004	0.065 ± 0.025	
180	0.097 ±0.005	0.049 ± 0.001	0.038 ± 0.003	0.061 ± 0.028	
190	0.097 ±0.005	0.044 ± 0.004	0.029 ± 0.000	0.056 ± 0.030	
	0.097 ±0.005	0.049 ± 0.005	0.037 ±0.006	0.061 ± 0.027	0.061 ^{c} ± 0.027
170	0.097 ±0.005	0.077 ± 0.002	0.049 ± 0.001	0.074 ± 0.022	
180	0.097 ±0.005	0.066 ± 0.004	0.041 ± 0.001	0.068 ± 0.025	
190	0.097 ±0.005	0.050 ± 0.001	0.031 ± 0.003	0.059 ± 0.030	
	0.097 ±0.005	0.064 ± 0.012	0.040 ± 0.008	0.067 ± 0.025	0.067 ^{b}± 0.025
Grand mean	**0.097 ^{a} ±0.000**	**0.061 ^{b} ± 0.012**	**0.043 ^{c} ± 0.010**	**0.067 ± 0.013**	**0.067 ±0.004**

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

The results in Table 11 showed cooking methods significantly ($p < 0.05$) affected vitamin B_6 content. It was observed in Table 11 that samples cooked by air frying (AF) had an average vitamin B_6 content of 0.226 mg/100 g, while samples cooked by baking (BK) had 0.223 mg/100 g, deep fat frying (DF) had 0.167 mg/100 g and grilling (GR) had mean vitamin B_6 content of 0.205 mg/100 g. The differences in vitamin B_6 content due to cooking methods were significant ($p < 0.05$) and AF cooked samples had significantly ($p <0.05$) higher vitamin B_6 content than DF and GR cooked samples, but not significant ($p > 0.05$) with BK cooked samples. The lower vitamin B_6 content of DF cooked samples compared to others could be attributed to leaching effect of vitamin B_6 into the cooking oil. Most of vitamin B_6 content of deep fat fried samples was lost by stripping or leaching out into the frying oil as reported by Leskova et al. (2006).These results are in line with reported findings by Lynch and Young [24] and Bakhru [25] who reported thermal reduction and vitamin B_6 losses by cooking. Cooking temperature significantly ($p < 0.05$) affected vitamin B_6 content of cooked chicken breast meat. The average vitamin B_6 contents at the cooking of 170, 180 and 190^{0}C were 0.220 mg/100 g, 0.208 mg/100 g and 0.187 mg/100 g, respectively. Thus, vitamin B_6 content significantly ($p < 0.05$) reduced with increase in cooking temperature. The differences in vitamin B_6 content caused by cooking temperatures were significant ($p< 0.05$). Cooking at 170^{0}C resulted to significantly ($p < 0.05$) higher vitamin B_6 content than cooking at 180^{0}C and 190^{0}C. The increased reduction in pyridoxine content of cooked samples with increasing cooking temperatures (170^{0}C to 190^{0}C) could be attributed to thermal degradation of high molecular weight proteins [24,30]. The reduction of vitamin B_6 content with increasing temperature could be attributed to thermal denaturation of cooking medium. The interaction between cooking methods and temperatures was significant ($p < 0.05$), suggesting that the differences in vitamin B_6 content caused by cooking methods were different at different cooking temperatures.

It could be deduced from Table 11 that the differences in vitamin B_6 content between AF and DF (AF – DF) and BK and DF (BK – DF) were increasing with increase in cooking temperatures. On the other hand, the differences in vitamin B_6 content between AF and BK (AF – BK) or AF and GR (AF – GR) or BK and GR) or DF and GR (DF –GR) were neither decreasing nor increasing with increase in cooking temperatures. It can be deduced from the interaction that DF cooked samples resulted to least vitamin B_6 content at each cooking temperature compared to other cooking methods. This may suggest that, in addition to moisture loss, soluble substances and vitamin B_6 content in meat were stripped and leached into the frying oil with the leaching being higher at higher temperatures. Although all products continued to reduce in vitamin B_6 content as temperature of cooking increased, the air fried (AF) products had the highest vitamin B_6 content at each cooking temperature, suggesting that there was less stripping of vitamin B_6 content and drip loss at each temperature compared with other cooking methods.

The results in Table 11 showed that cooking time affected vitamin B_6 content. The average vitamin B_6 contents at 8 and 16 min were 0.206 mg/100g and 0.167 mg/100g. Thus vitamin B_6 content significantly ($p < 0.05$) reduced as cooking time increased. The differences are attributed to long time exposure 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 vitamin B_6 content due to the cooking methods were different at different cooking times. The significant interaction ($p < 0.05$) showed that the differences in vitamin B_6 content between AF and DF (AF - DF), AF and GR (AF – GR), BK and DF (BK - DF) and BK and GR (BK and GR) were increasing with increase in cooking times, but the differences in vitamin B_6 content between AF and BK (AF - BK) were neither increasing nor decreasing with increase in cooking times. On the other hand, the differences in vitamin B_6 content between DF and GR (DF - GR) were decreasing with increase in cooking times. There was significant interaction ($p < 0.05$) between cooking temperatures and cooking times. The differences in vitamin B_6 content 170 and 180 ^{0}C (170 - 180^{0}C), 170 and 190^{0}C (170 - 190^{0}C) and 180 and 190^{0}C (180 - 190^{0}C) were decreasing with increase in cooking times. However, the overall interaction (Method x Temperature x Time) was found to be significant. This significant ($p < 0.05$) overall interaction confirmed why the products deep fat fried (DF) at 190^{0}C and 16 min had the least vitamin B_6 content (0.046 mg/100 g), while the products obtained by air fried (AF) at 170^{0}C for 8 min had the highest vitamin B_6 content (0.236 mg/100 g). The higher reduction of vitamin B_6 in samples cooked at 190^{0}C for 16 min agrees with findings by Eitenmiller and

Laden [31], Leskova et al. (2006) and Catak and Caman [32] who reported increased heat degradation of vitamin B_6 in animal products and heat degradation in the range of 40 – 58% in animal foods. The coefficient of determination R^2 is 99.6 %. This value is very high, indicating treatment variables and their interactions affected the observed decreases in vitamin B_6 content.

The results in Table 12 showed the vitamin B_9 (folic acid) content of chicken breast meat. Cooking methods significantly ($p < 0.05$) affected vitamin B_9 content. On the average, vitamin B_9 content reduced to an overall mean of 0.116 mg/100 g. The reduction in vitamin B_9 content of chicken breast meat cooked with different cooking methods could be attributed to thermal denaturation of proteins and leaching out of the vitamin. It was observed in Table 12 that samples cooked by air frying (AF) had an average vitamin B_9 content of 0.117 mg/100 g, samples cooked by baking (BK) had 0.125 mg/100 g, deep fat frying (DF) had 0.099 mg/100 g, while grilling (GR) had mean vitamin B_9 content of 0.122 mg/100 g. The differences in vitamin B_9 content due to cooking methods were significant ($p < 0.05$) and samples cooked by BK had significantly ($p < 0.05$) higher vitamin B_9 content than others. The lower vitamin B_9 content of DF cooked samples could be attributed to thermal denaturation of high molecular weight proteins as reported by Lynch and Young [24] and Murphy and Marks [30] compared to others methods.

Cooking temperature significantly ($p < 0.05$) affected vitamin B_9 content of cooked chicken breast meat. The average vitamin B_9 contents of cooking at 170, 180 and 190^{0}C were 0.130 mg/100 g, 0.114 mg/100 g and 0.105 mg/100 g, respectively. Thus, vitamin B_9 content significantly ($p < 0.05$) reduced with increase in cooking temperatures. The differences in vitamin B_9 content caused by cooking temperatures were significant ($p < 0.05$). Cooking at 170^{0}C resulted to significantly ($p < 0.05$) higher vitamin B_9 content than cooking at 180℃ and 190℃. Heat emanating from the cooking caused thermal degradation of high molecular weight proteins and reduction of vitamin B_9 content of the substrate. The reduction of vitamin B_9 content with increasing temperature could be attributed to thermal denaturation of high molecular weight proteins [24,30]. The interaction between cooking methods and temperatures was significant ($p < 0.05$), suggesting that the differences in vitamin B_9 content caused by different cooking methods were different at different cooking temperatures. It could be deduced from Table 12 that the differences in vitamin B_9 conten between AF and BK (AF – BK), AF and GR (AF – GR) and BK and DF (BK – DF) were increasing with increase cooking temperatures, while the differences in vitamin B_9 content between AF and DF (AF – DF) were decreasing with increase cooking temperatures. On the other hand, the differences in vitamin B_9 content between BK and GR (BK - GR) or DF and GR (DF – GR) were similar with increase cooking temperatures. It could be deduced from interaction that DF cooked samples resulted to least vitamin B_9 content at each cooking temperature compared to other cooking methods. This may suggest that, in addition to moisture loss, soluble substances and vitamin B_9 content in meat were stripped and leached into the frying oil. This finding agrees with Al-Khalifa and Dawood [26], Czarnowska-Kujawska et al. [33] and Alugwu and Alugwu [28] who reported higher losses of Vitamin B_9 during roasting, deep-fat frying and grilling of chicken meat. Although all products continued to reduce in vitamin B_9 content as temperature of cooking increased, the baked (BK) products had the highest vitamin B_9 content at each cooking temperature, suggesting that there was less stripping of vitamin B_9 content and drip loss at each temperature compared with other cooking methods.

The results in Table 12 showed that cooking time affected vitamin B_9 content. The average vitamin B_9 contents at 8 and 16 min were 0.110 mg/100 g and 0.087 mg/100 g, respectively. Thus vitamin B_9 content significantly ($p < 0.05$) reduced as cooking time increased. This finding agrees with reported findings by Lynch and Young [24], Murphy and Marks [30] and Alugwu and Alugwu [28] who observed that increased reduction of vitamin B_9 content with increasing cooking temperature and time. The differences are attributed to long time exposure 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 vitamin B_9 content due to the cooking methods were different at different cooking times. The significant interaction ($p < 0.05$) showed that the differences in vitamin B_9 content between AF and GR (AF – GR) and DF and GR (DF – GR) were increasing with increase in cooking times, while differences in vitamin B_9 content between AF and BK (AF - BK), AF and DF (AF - DF), BK and DF (BK - DF) and BK and GR (BK – GR) were decreasing with increase in cooking times.

There was significant interaction ($p < 0.05$) between cooking temperatures and cooking times. The differences in vitamin B_9 content between170 and 180 ^{0}C (170 - 180 ^{0}C), 170 and 190^{0}C (170 - 190^{0}C) and 180 and 190^{0}C (180 - 190^{0}C) were decreasing with increase in cooking times. Furthermore, the overall interaction (Method x Temperature x Time) was found to be significant. This significant ($p < 0.05$) overall interaction confirmed why the products deep fat fried (DF) at 190 ℃ for 16 min had the least vitamin B_9 content (0.052 mg/100 g), while the products obtained by baking (BK) at 170^{0}C for 8 min had the highest vitamin B_9 content (0.146 mg/100 g). The coefficient of determination R^2 is 98.7 %. This value is very high, indicating treatment variables and their interactions affected the observed decreases in vitamin B_9 content.

The results in Table 13 showed the vitamin B_{12} (Cyanocobalamin) content of chicken breast meat. Cooking methods significantly ($p < 0.05$) affected vitamin B_{12} content. On the average, cooking reduced vitamin B_{12} content to an overall mean of 0.108 mg/100 g. The reduction in vitamin B_{12} content of chicken breast meat cooked with different cooking methods could be attributed to thermal denaturation of proteins and leaching out of the vitamin B_{12}. It was observed in Table 13 that samples cooked by air frying (AF) had an average vitamin B_{12} content of 0.109 mg/100 g, samples cooked by baking (BK) had 0.117 mg/100 g, deep fat frying (DF) had 0.109 mg/100 g, while grilling (GR) had mean vitamin B_{12} content of 0.098 mg/100 g. The differences in vitamin B_{12} content due to cooking methods were significant ($p < 0.05$) and samples cooked by BK method had significantly ($p <0.05$) higher vitamin B_{12} content than other cooking methods. Samples cooked by GR method had the highest percent vitamin B_{12} content reduction. The result disagrees with findings of Czerwonka et al. [34] who stated that DF method had the highest losses of vitamin B_{12} content (32%) and more losses occur on surface due to direct contact compared with control meat.

Cooking temperature significantly ($p < 0.05$) affected vitamin B_{12} content of cooked chicken breast meat. The average vitamin B_{12} contents of cooking at 170, 180 and 190 ^{0}C were 0.121 mg/100 g, 0.109 mg/100 g and 0.094 mg/100 g, respectively. Thus, vitamin B_{12} content significantly ($p < 0.05$) reduced with increase in cooking temperature. The differences in vitamin B_{12} content caused by cooking temperatures were significant ($p < 0.05$). Cooking at170℃ resulted to significantly ($p < 0.05$) higher vitamin B_{12} content than cooking at 180 ^{0}C and 190^{0}C. Heat emanating from the cooking caused thermal denaturation of high molecular weight proteins and reduction of vitamin B_{12} content of the substrate. The reduction of vitamin B_{12} content with increasing temperature could be attributed to thermal degradation of high molecular weight proteins [24,30]. The interaction between cooking methods and temperatures was not significant ($p > 0.05$), suggesting that the differences in vitamin B_{12} content caused by different cooking methods were similar at each cooking temperatures. The results in Table 13 showed that cooking time affected vitamin B_{12} content. The average vitamin B_{12} contents for 8 and 16 min were 0.102 mg/100 g and 0.055 mg/100 g, respectively. Thus vitamin B_{12} content significantly ($p < 0.05$) reduced as cooking time increased. This finding agrees with reported findings by Lynch and Young [24] and Murphy and Marks [30] who observed that increased reduction of vitamin B_{12} content with increased cooking temperature and time. The differences are attributed to long time exposition of the products in the cooking medium. The interaction between the cooking methods and cooking times was found to be significant ($p < 0.05$). This suggests that the vitamin B_{12} content due to the cooking methods were different at different cooking times. The differences in vitamin B_{12} content between AF and BK (A F - BK), AF and GR (AF – GR) and BK and DF (BK – DF) were increasing with increase in cooking times, while AF and DF (AF – D) were similar with increase cooking. On the other hand, the differences in vitamin B_{12} content between BK and GR (BK - GR) 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 significant ($p < 0.05$). The differences in vitamin B_{12} content between 170 and 180^{0}C (170 - 180^{0}C) and 170 and 190^{0}C (170 - 190^{0}C) were decreasing with increase in cooking times. On the other hand, the differences in vitamin B_{12} content between 180 and 190^{0}C (180 - 190^{0}C) were increasing with increase cooking times.

Table 10. Vitamin B_3 (mg/100 g) of chicken breast at different cooking method, temperature and time

Cooking	Cooking	Cooking time (min)			Mean cooking	
Method	**Temp^{0}C**	**0**	**8**	**16**	**Temp ℃**	**Method**
AF	170	0..037 ± 0.001	0.034 ± 0.000	0.023 ± 0.001	0.031 ± 0.007	
	180	0..037 ± 0.001	0.027± 0.000	0.020 ± 0.001	0.028 ± 0.008	
	190	0..037 ± 0.001	0.023 ± 0.001	0.015 ± 0.001	0.025 ± 0.010	
Mean		0..037 ± 0.001	0.028 ± 0.005	0.019 ± 0.004	0.028 ± 0.008	0.028 ^{b} ± 0.008
BK	170	0..037 ± 0.001	0.022 ±0.001	0.017 ±0.001	0.025 ± 0.010	
	180	0..037 ± 0.001	0.019 ± 0.01	0.016 ± 0.001	0.024 ± 0.010	
	190	0..037 ± 0.001	0.014 ± 0.001	0.012 ± 0.001	0.021 ± 0.013	
Mean		0..037 ± 0.001	0.018 ± 0.004	0.015 ± 0.003	0.023 ± 0.010	0.023 ^{c}± 0.010
DF	170	0..037 ± 0.001	0.033 ± 0.001	0.025 ± 0.001	0.032 ± 0.006	
	180	0..037 ± 0.001	0.029 ± 0.002	0.022 ± 0.001	0.029 ± 0.007	
	190	0..037 ± 0.001	0.024 ± 0.001	0.019 ± 0.001	0.026 ±0.009	
Mean		0..037 ± 0.001	0.029 ± 0.004	0.022 ± 0.003	0.029 ± 0.007	0.029^a± 0.007
GR	170	0..037 ± 0.001	0.022± 0.001	0.017 ± 0.000	0.025 ± 0.009	
	180	0..037 ± 0.001	0.019 ± 0.001	0.016 ± 0.000	0.023 ± 0.010	
	190	0..037 ± 0.001	0.015 ± 0.000	0.014 ± 0.001	0.022 ± 0.012	
Mean		0..037 ± 0.001	0.018 ± 0.003	0.016 ± 0.002	0.024 ± 0.010	0.024 ^{c} ± 0.010
Grand mean		**0..037 ^{a} ± 0.001**	**0.023 ^{b}± 0.006**	**0.018 ^{c}± 0.004**	**0.026 ± 0.009**	**0.026 ±0.003**

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 11. Vitamin B_6 (mg/100 g) of chicken breast meat at different cooking method, temperature and time

	Cooking	Cooking time (min)			Mean cooking	
Method	**Temp ^{0}C**	**0**	**8**	**16**	**Temp ℃**	**Method**
AF	170	0.242 ± 0.001	0.236 ± 0.004	0.215 ± 0.002	0.231 ± 0.013	
	180	0.242 ± 0.001	0.220 ± 0.004	0.212 ± 0.001	0.225 ± 0.004	
	190	0.242 ± 0.001	0.219 ± 0.001	0.211 ± 0.001	0.224 ± 0.01	
Mean		0.242 ± 0.001	0.225 ± 0.009	0.212 ± 0.002	0.226 ± 0.013	0.226 ^{a}± 0.013
BK	170	0.242 ± 0.001	0.221 ± 0.001	0.218 ± 0.001	0.226 ± 0.12	
	180	0.242 ± 0.001	0.217 ± 0.001	0.212 ± 0.005	0.223 ± 0.014	
	190	0.242 ± 0.001	0.214 ± 0.004	0.205 ± 0.010	0.220 ± 0.017	
Mean		0.242 ± 0.001	0.217 ± 0.005	0.212 ± 0.008	0.223 ± 0.014	0.223 ^{a} ± 0.014
DF	170	0.242 ± 0.001	0.200 ± 0.006	0.155± 0.002	0.199 ± 0.039	
	180	0.242 ± 0.001	0.164 ± 0.006	0.080 ± 0.005	0.162 ± 0.073	
	190	0.242 ± 0.001	0.139 ± 0.006	0.046 ± 0.011	0.142 ± 0.088	
Mean		0.242 ± 0.001	0.167 ± 0.028	0.093 ± 0.050	0.167 ± 0.070	0.167 ^{c} ± 0.070
GR	170	0.242 ± 0.001	0.221 ± 0.004	0.207 ± 0.002	0.223 ± 0.016	
	180	0.242 ± 0.001	0.216 ± 0.007	0.205 ± 0.006	0.221 ± 0.17	
	190	242 ± 0.001	0.212 ± 0.006	0.036± 0.009	0.163 ± 0.100	
Mean		0.242 ± 0.001	0.216 ± 0.006	0.149 ± 0.088	0.205 ± 0.062	0.205 ^{b} ± 0.062
Grand mean		**0.242 ^{a} ± 0.001**	**0.206 ^{b} ± 0.027**	**0.167 ^{c} ± 0.069**	**0.205 ± 0.052**	**0.205 ±0.027**

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 12. Vitamin B_9 (mg/100 g) of chicken breast meat at different cooking method, temperature and time

Cooking	Cooking	Cooking time (min)			Mean cooking	
Method	Temp ^{0}C	0	8	16	Temp ℃	Method
AF	170	0.151 ±0.003	0.134± 0.001	0.122 ± 0.002	0.135 ± 0.034	
	180	0.151 ±0.003	0.118 ± 0.001	0.076 ± 0.007	0.115 ± 0.134	
	190	0.151 ±0.003	0.090 ± 0.002	0.061 ± 0.003	0.101 ± 0.041	
Mean		0.151 ±0.003	0.114 ± 0.020	0.086 ± 0.028	0.117 ± 0.033^b	0.117 ^{b} ± 0.033
BK	170	0.151 ±0.003	0.146 ± 0.008	0.115 ± 0.000	0.137 ± 0.018	
	180	0.151 ±0.003	0.125 ± 0.016	0.095 ± 0.004	0.124 ± 0.026	
	190	0.151 ±0.003	0.111 ± 0.001	0.085 ± 0.006	0.116 ± 0.030	
Mean		0.151 ±0.003	0.127 ± 0.018	0.098 ± 0.014	0.125 ±0.025^a	0.125 ^{a} ±0.025
DF	170	0.151 ±0.003	0.115 ± 0.001	0.074 ± 0.005	0.113 ± 0.034	
	180	0.151 ±0.003	0.082 ± 0.002	0.060 ± 0.001	0.097 ± 0.042	
	190	0.151 ±0.003	0.061 ± 0.001	0.052 ± 0.002	0.088 ± 0.049	
Mean		0.151 ±0.003	0.086 ±0.024	0.062 ± 0.10	0.099 ± 0.041^c	0.099 ^{c} ± 0.041
GR	170	0.151 ±0.003	0.136 ± 0.001	0.112 ± 0.018	0.133 ± 0.019	
	180	0.151 ±0.003	0.105 ± 0.006	0.102 ± 0.008	0.119 ± 0.025	
	190	0.151 ±0.003	0.103 ± 0.003	0.091 ± 0.001	0.115 ± 0.017	
Mean		0.151 ±0.003	0.115±0.017	0.101 ±0.013	0.122 ± 0.024^a	0.122 ^{a} ± 0.024
Grand mean		**0.151 ^{a} ±0.002**	**0.110 ^{b} ± 0.024**	**0.087 ^{c} ± 0.023**	**0.116 ±0.033**	**0.116±0.012**

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 13. Vitamin B_{12} (mg/100 g) of chicken breast meat at different cooking method, temperature and time

Cooking	Cooking	Cooking time (min)			Mean cooking	
Method	Temp ^{0}C	0	8	16	Temp ℃	Method
AF	170	0.168 ± 0.003	0.143 ± 0.005	0.058 ± 0.001	0.123 ± 0.052	
	180	0.168 ± 0.003	0.108 ± 0.001	0.053 ± 0.012	0.109 ± 0.052	
	190	0.168 ± 0.003	0.088± 0.001	0.031 ± 0.001	0.095 ± 0.062	
Mean		0.168 ± 0.002	0.113 ± 0.025	0.047 ± 0.014	0.109 ± 0.053	0.109^{b} ± 0.053
BK	170	0.168 ± 0.003	0.128 ± 0.008	0.103 ± 0.013	0.133 ± 0.030	
	180	0.168 ± 0.003	0.123 ± 0.015	0.065 ± 0.000	0.115 ± 0.051	
	190	0.168 ± 0.003	0.099 ± 0.009	0.042 ± 0.004	0.103 ± 0.057	
Mean		0.168 ± 0.002	0.116 ± 0.017	0.067 ± 0.029	0.117 ± 0.046	0.117^{a}± 0.046
DF	170	0.168 ± 0.003	0.139 ± 0.010	0.073 ± 0.000	0.121 ± 0.052	
	180	0.168 ± 0.003	0.096 ± 0.001	0.057 ± 0.000	0.112 ± 0.044	
	190	0.168 ± 0.003	0.086 ± 0.007	0.028 ± 0.006	0.094 ± 0.063	
Mean		0.168 ± 0.002	0.107 ± 0.026	0.053 ± 0.021	0.109 ± 0.052	0.109^{b} ± 0.052
GR	170	0.168 ± 0.003	0.093 ± 0.003	0.062 ± 0.000	0.108 ±0.049	
	180	0.168 ± 0.003	0.071 ± 0.003	0.059 ± 0.001	0.100 ± 0.053	
	190	0.168 ± 0.003	0.052 ± 0.012	0.037 ± 0.001	0.086 ± 0.064	
Mean		0.168 ± 0.002	0.072 ± 0.019	0.053 ± 0.013	0.098 ± 0.053	0.098^{c} ± 0.053
Grand mean		**0.168^{a} ± 0.002**	**0.102^{b}± 0.027**	**0.055^{c}± 0.020**	**0.108 ±0.051**	**0.108±0.008**

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 14. Vitamin C (mg/100 g) of chicken breast meat at different cooking method, temperature and time

Cooking	Cooking	Cooking time (min)			Mean cooking	
Method	Temp^{0}c	0	8	16	Temp ℃	Method
AF	170	0.145±0.004	0.126 ± 0.004	0.121 ± 0.002	0.130 ± 0.012	
	180	0.145±0.004	0.114 ± 0.001	0.096 ± 0.002	0.118 ±0.022	
	190	0.145±0.004	0.100 ± 0.001	0.089± 0.006	0.111 ± 0.027	
Mean		0.145±0.004	0.113±0.012	0.102±0.015	0.120± 0.022	0.120 ^{a} ± 0.022
BK	170	0.145 ±0.004	0.096 ±0.001	0.089 ±0.006	0.110 ± 0.027	
	180	0.145 ±0.004	0.088±0.001	0.083 ±0.001	0.105 ± 0.001	
	190	0.145±0.004	0.076 ±0.001	0.070 ±0.001	0.097 ± 0.037	
Mean		0.145±0.004	0.087±0.009	0.081±0.009	0.104 ±0.031	0.104 ^{b} ± 0.031
DF	170	0.145 ±0.004	0.077 ± 9.003	0.073 ± 0.003	0.098 ± 0.036	
	180	0.145 ±0.004	0.069 ±0.004	0.063 ±0.001	0.092 ± 0.041	
	190	0.145±0.004	0.052 ±0.001	0.047 ± 0.001	0.081 ± 0.049	
Mean		0.145±0.004	0.066±0.012	0.061±0.012	0.090±0.041	0.090 ^{d} ±0.041
GR	170	0.145±0.004	0.081±0.002	0.078 ± 0.002	0.101 ± 0.034	
	180	0.145±0.004	0.078±0.001	0.074 ±0.001	0.099 ± 0.036	
	190	0.145±0.004	0.061 ±0.001	0.056 ±0.001	0.087 ± 0.005	
Mean		0.145±0.004	0.073±0.009	0.069±0.010	0.096 ±0.037	0.096 ^{c} ± 0.037
Grand mean		**0.145 ^{a} ±0.006**	**0.085 ^{b} ±0.021**	**0.078^{c}± 0.019**	**0.102 ± 0.034**	**0.103±0.013**

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

However, the overall interaction (Method x Temperature x Time) was found to be significant. This significant ($p < 0.05$) overall interaction confirmed why the products deep fat fried (DF) at 190^0C for 16 min had the least vitamin B_{12} content (0.028 mg/100 g), while the products obtained by air fried (AF) at 170^0C for 8 min had the highest vitamin B_{12} content (0.143 mg/100 g). The coefficient of determination R^2 is 99.4%. This value is very high, indicating treatment variables and their interactions affected the observed decreases in vitamin B_{12} content.

The results in Table 14 showed the vitamin C (ascorbic acid) content of chicken breast meat. Cooking methods significantly ($p < 0.05$) affected vitamin C content. On the average, vitamin C content reduced to an overall mean of 0.103 mg/100 g. This research result was lower than reported value of 2.30 mg/ 100g by Pamplona-Roger [35]. The reduction in vitamin C content of chicken breast meat treated with different cooking methods could be attributed to thermal degradation of proteins and leaching out of the vitamin C. It was observed in Table 14 that samples cooked by air frying (AF) had an average vitamin C content of 0.120 mg/100 g, samples cooked by baking (BK) had 0.104 mg/100 g, deep fat frying (DF) had 0.090 mg/100 g, while grilling (GR) had mean vitamin C content of 0.096 mg/100 g. The differences in vitamin C content due to cooking methods were significant ($p < 0.05$) and samples cooked by AF had significantly ($p <0.05$) higher vitamin C content than others, while samples cooked by DF method had the least percent vitamin C content. Cooking temperature significantly ($p < 0.05$) affected vitamin C content of cooked chicken breast meat. The average vitamin C contents of cooking at 170, 180 and 190℃ were 0.110 mg/100 g, 0.103 mg/100 g and 0.094 mg/100 g, respectively. Thus, vitamin C content significantly ($p < 0.05$) reduced with increase in cooking temperatures. The differences in vitamin C content caused by cooking temperatures were significant ($p < 0.05$). Cooking at 170℃ resulted to significantly ($p < 0.05$) higher vitamin C content than cooking at 180^0C and 190^0C. Heat emanating from the cooking caused thermal degradation of high molecular weight proteins and reduction of vitamin C content of the substrate [36,37]. The reduction of vitamin C content with increasing temperature could be attributed to thermal denaturation of high molecular weight proteins [24,30]. The interaction between cooking methods and temperatures was not significant ($p > 0.05$). This suggests that the differences in vitamin C content caused by different cooking methods were similar at each cooking temperatures. The results in Table 14 showed that cooking time affected vitamin C content. The average vitamin C contents at 8 and 12 min were 0.102 mg/100 g and 0.055 mg/100 g, respectively. Thus vitamin C content significantly ($p < 0.05$) reduced as cooking time increased. The interaction between the cooking method and cooking times was found to be significant ($p < 0.05$). This suggests that the vitamin C content due to cooking methods were different at different cooking times. The significant interaction ($p < 0.05$) showed that the differences in vitamin C content between DF and GR (DF – GR) were increasing with increase cooking times, while the differences in vitamin C content between AF and BK (AF- BK), AF and DF (AF – DF), AF and GR (AF – GR), BK and DF (BK - DF) and BK and GR (BK - GR) were decreasing with increase in cooking times. There was significant interaction ($p < 0.05$) between cooking temperatures and cooking times. The differences in vitamin C content between 170 and 180^0C (170 - 180^0C) were increasing with increase in cooking times. Similarly, the differences in vitamin C content between 170 and 190^0C (170 - 190^0C) and 180 and 190^0C (180 - 190^0C) were decreasing with increase in cooking times. However, the overall interaction (Method x Temperature x Time) was not found to be significant. The vitamin C coefficient of determination R^2 is 99.0%. This value is very high, indicating treatment variables and their interactions affected the observed decreases in vitamin C content.

4. CONCLUSION

Thermal treatments increased the amount of water lost in cooked breast meat. The micronutrient contents of cooked breast meat decreased together with water and other water soluble components (dissolved collagen, connective tissues and sarcoplasmic proteins) either by evaporating or dripping of expelled water soluble substances with meat juice. Cooking conditions cause vary losses of stable minerals and unstable vitamins in muscle foods. The ascending percentage reduction of mean minerals in cooked chicken breast were Zn, P, K, Fe, Na and Ca, whereas Mg increased by 16.01 %. The percentage reduction of mean minerals by the cooking methods were AF (22.09%), BK (16.41%), DF (22.48%) and GR (17.08%).Whereas the ascending percentage reduction of mean vitamins were B_6, B_9, C, B_3,

B_2, B_{12} and B_1. The mean percentage vitamins reduction by the cooking methods were AF (25.39%), BK (26.88%), DF (36.04%) and GR (30.69%). High cooking temperatures and times result in greater minerals reduction except Mg and vitamins losses. Samples cooked at 170 ^{0}C for 4 min and 170 ^{0}C for 8 min have lower losses of minerals and vitamins compared to similar samples cooked at 180^{0}C and 190^{0}C.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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