ISSN:
Print - 2277 - 0755
Online - 2315 - 7453

Journal of Agricultural Science and Environment

MEAT QUALITY AND LIPID PROFILE OF BROILER CHICKENS FED DIETS CONTAINING TURMERIC (*CURCUMA LONGA*) POWDER AND CAYENNE PEPPER (*CAPSICUM FRUTESCENS*) POWDER AS ANTIOXIDANTS

***[1]K. A. SANWO, [1]A.V. ADEGOKE, [1]L.T. EGBEYALE, [2]J.A. ABIONA, [3]R.A. SOBAYO, [1]O.V. OBAJULUWA AND [1]A.O. ABDULAZEEZ**

[1]Department of Animal Production and Health, Federal University of Agriculture, Abeokuta, Abeokuta, Nigeria.
[2]Department of Animal Breeding and Genetics, Federal University of Agriculture, Abeokuta.
[3]Department of Animal Nutrition, Federal University of Agriculture, Abeokuta.
***Corresponding Author:**bumogardens@yahoo.com **Tel**: +234

ABSTRACT
This experiment was designed to determine the meat quality and lipid profile of broiler chickens fed diets containing turmeric (*Curcuma longa*) powder (Tur) and cayenne pepper (*Capsicum frutescens*) powder (Cay) as antioxidants. Two hundred and forty three (two-week old) Abor Acre broiler chicks were randomly allotted to nine treatment groups of 27 birds each, consisting of three replicates of nine birds each in a completely randomised design. Three levels of Tur (0, 2 and 4 g/kg) and three levels of Cay (0, 1 and 2 g/kg) were used to provide nine dietary treatments. Meat quality indices such as cook and refrigerated losses, water absorptive power, etc were measured and determined at the 8th week. Broiler Chickens fed the basal diet had highest meat dry matter, protein content and least ($p<0.05$) meat pH, cook and refrigeration loss values. Meat triglyceride and meat malondialdehyde value was best ($p<0.05$) in treatments fed dietary 2 g/kg Cay, while chickens fed 2 g/kg Cay, 2 g/kg Tur + 1 g/kg Cay and 2 g/kg Tur + 2 g/kg Cay had better meat lipoprotein values. For meat sensory characteristic, meat flavour of broiler chickens fed diets containing 2 and 4 g/kg dietary Tur, were moderately liked while overall flavour was best ($p<0.05$) in groups fed the basal diet with no dietary additive. It was evident in the study that the dietary inclusions of the test ingredients limited lipid oxidation, thus improved storage duration and meat flavor.

Keywords: *Turmeric, cayenne pepper, cook and refrigeration loss, pH, sensory, TBARS,*

INTRODUCTION
Socio-economic factors, changed lifestyle and health consciousness have led to increased demand for safe and healthy meat and its products. Micha *et al*. (2010) research on the image of meat and meat products reveal relative negativity can be aggravated by fat content, saturated fatty acid, cholesterol and sodium, which is a possible mediator of most prevalent diseases of western societies like cardiovascular diseases and diabetes mellitus. Meat quality parameters are univer-

sally accepted criteria for consumer perception, acceptance and subsequent storage capacity.

Among animal-source foods, poultry meat has been traditionally documented to be highly sensitive to oxidative processes caused by the presence of high unsaturated fatty acids in the muscles (Min *et al*., 2008). Lipid oxidation is a major cause of meat quality deterioration, as oxidative stress (OS), termed a metabolic disturbance can negatively influence organ systems that can affect livestock health and quality of final products produced, such as meat and milk (Castillo *et al*., 2006). The pro-oxidative environment created in postmortem muscles upon animal slaughter leads to the occurrence of oxidative reactions during ageing, handling, processing, and storage of muscle foods. The alterations of oxidative rancidity that occur in meat and meat products can vary greatly, ranging from rancid odour changes, colour losses and structural damage on proteins to a subtle loss of freshness" that can put off consumers. High amount of unsaturated fatty acids deposited in broiler chicken meat leads to subsequent rancidity and off-flavour taste.

There is growing interest in the production of functional foods where nutrient composition is adjusted to provide a benefit to the consumer. It is imperative to protect meat as good as possible from oxidation through meat formulation process and subsequent storage. Natural antioxidants have been used to control and improve meat stability and quality.Herbs and spices as antioxidants have been incorporated into livestock diet or used as herbal remedies targeted at improving meat quality, palatability and storage potential. (Gurikar *et al*., 2014; Reddy *et al*., 2015 and Reddy *et al*., 2015). Phenolic compounds are secondary plant metabolites which act as an antioxidant (Ross and Kasum, 2007).

Capsaisin, the principal antioxidant present in cayenne pepper (*Capsicum frutescens*) has been demonstrated to suppress fat accumulation and oxidation (Snitker *et al*., 2009), inhibits the inflammatory process (Kang *et al*., 2010) suppress total cholesterol and low density lipoprotein and triglycerides in rats (Medvedeva *et al*., 2003 and Ahuja *et al*., 2006). Turmeric powder (*Curcuma longa*) on the other hand is a polyphenolic medicinal plant that belongs to the ginger (Zingiberaceae) family which is also a major source antioxidants (curcuminoids). Turmeric according to Pal *et al.* (2001) is a potent antioxidant and anti-inflammatory agent. Curcumin reduces the activity of reactive oxygen species and elevates the antioxidant enzymes (Wuthi-Udomler *et al*., 2000). Hence, this study is designed to experiment the anti-oxidative effect of turmeric (*Curcuma longa*) powder and cayenne pepper (*Capsicum frutescens*) powder on meat quality of broiler chickens.

MATERIALS AND METHODS

Experimental Site

The experiment was carried out at the Poultry Unit of Directorate of University Farms (DUFARMS), Federal University of Agriculture Abeokuta, Ogun State, Nigeria. The site is located in the rain forest vegetation zone of South-Western Nigeria on latitude 7^{o} 13' 49.46'' N, longitude 3^{o} 26 11.98E and altitude 76m above the sea level.(Google Earth, 2013). Meat quality assessment was carried out at the Animal Product Laboratory in the Department of Animal Production and Health, Federal University of Agriculture, Abeokuta.

Research Policy

This study was conducted under the supervision and approval of the Animal Ethics Committee guidelines of the Federal University of Agriculture, Abeokuta (FUNAAB, 2015) Experimental Materials (Test Ingredients). Dried rhizomes of turmeric and cayenne pepper were bought from a local market and milled with the attrition mill separately into powdery form and were added into the basal diets at appropriate levels of inclusion.

Experimental Management and Layout

A total of 243 day old broiler (Arbor acres) chicks were obtained from a reputable hatchery in Ibadan. The birds were brooded together for the first two weeks in a deep litter pen. Vaccinations and medication required were administered following a recommended schedule of an established farm during the experiment.

At the end of 2 weeks of collective brooding, the birds were randomly assigned into nine treatment groups, each consisting of 27 birds. Each treatment was further replicated thrice, containing 9 birds per replicate. Experiment consisted of starter (3-4 weeks) and finisher (5 to 8 weeks) phases, and experimental diets were assigned to each of the 9 treatment groups while feeding *ad libitum*. Clean water was adequately provided daily. The basal diets given are shown in Table 1.

Table 1: Basal Composition of the Experimental Diets at Starter and Finisher Phases for Broiler Chickens

INGREDIENTS	STARTER PHASE (%)	FINISHER PHASE (%)
Maize	52.00	58.40
Wheat bran	4.30	10.60
Soyabean Meal	18.50	10.00
Groundnut Cake	17.00	14.00
Fishmeal	2.20	1.00
Bonemeal	3.00	3.00
Limestone	2.00	2.00
Salt	0.25	0.25
*Mineral and Vitamin Premix	0.25	0.25
Methionine	0.25	0.25
Lysine	0.25	0.25
Total	100.00	100.00
Determined Analysis		
Crude Protein (%)	23.09	19.11
M. E (MJ/kg)	12.10	12.03
Crude Fibre	3.47	3.50
Ether extract	4.17	3.93
Calcium	1.40	1.38
Phosphorus	0.71	0.69

*Premix composition per kg diet: Vit A: 400,000.00 IU, Vit D3: 800,000.00 IU, Vit E: 9,200.00mg, Vit k: 800.00mg, Vit B1: 1000.00mg, Vit B6: 500.00mg, Vit B12: 25.00mg, Niacin: 6000.00mg, Pantothenic acid: 2000.00mg, Folic acid: 200.00mg, Biotin: 8mg, Mn: 300,000.00g, Zn: 20,000.00g, Cobalt: 80.00mg, I: 40.00mg, Choline: 80,000.00g, Antioxidants: 800.00mg

All diets were formulated using nutrient requirement established by the NRC (1994).
Treatment (T) 1- Basal diet (No dietary Supplementation); T2 - Basal diet + 200 g Turmeric Powder (B+200t); T3 - Basal diet + 400 g Turmeric Powder (B+400t) ; T4- Basal diet + 100 g Cayenne Pepper Powder (B+100c) ;T5 - Basal diet + 200 g Cayenne Pepper Powder (B+200c)
T6 - Basal diet + 200 g Turmeric Powder + 100 g Cayenne pepper powder (B+200t+100c)
T7 – Basal diet + 400 g Turmeric Powder + 100 g Cayenne pepper Powder (B +400t+100c)
T8 – Basal diet + 200 g Turmeric Powder + 200 g Cayenne pepper Powder (B+200t+200c)
T9 – Basal diet + 400 g Turmeric Powder + 200 g Cayenne pepper (B+400t +200c)

Proximate Composition of Test Ingredient and Meat

Proximate composition (moisture, crude protein (CP), ether extract (EE), carbohydrate and ash content) of turmeric rhizome powder, cayenne pepper, test diets and meat samples were determined by AOAC methods (AOAC, 2005).

Meat Quality Determination

Determination of Cooking Loss of Broiler Meat

Fifty (50) grams of the thigh muscle of meat samples from each replicate was weighed, wrapped in separate air-tight polythene bag and cooked in a water bath at 70°C for 30 minutes (Sanwo *et al*., 2012), and the losses were determined as follows:

Cooking loss (g) = Weight before cooking – Weight after cooking
Cooking loss (%) = (Weight before cooking – Weight after cooking × 100)/Weight before cooking.

Determination of Refrigeration Loss of Broiler Meat

Approximately 50 g of thigh muscle from each replicate was weighed and labeled before refrigeration and re-weighed after 24 hours of refrigeration to determine the refrigerated loss as follows:
Refrigeration loss (g) = weight before refrigeration – weight after refrigeration
Refrigeration loss (%) = (weight before refrigeration – weight after refrigeration × 100)/Weight before refrigeration

Determination of Meat Water Absorptive Power

Three grams (3 g) each of carcass sample from the thigh muscle of each replicate was weighed and placed in clean test-tubes; 10 mls of distilled water was poured in the test tube and left for an hour. After one hour, each sample was removed and reweighed. The increase in the weight of the sample indicated the volume of water absorbed.

Muscle pH

Approximately 10 g of each carcass sample from thigh muscle was weighed and placed in a clean sauce pan for pH reading. The pH value was recorded by placing the same electrode of the hand held pH meter (model pH – 108A) deeply into the meat after rinsing electrode in distilled water (Kim *et al*., 2009).

Determination of Meat lipid profile

Three replicate samples of the thigh muscles (5g) from each treatment were taken as samples for the cholesterol analysis and carried out according to the method described by (Folch *et al*., 1957).

MDA Determination using 2-Thiobarbituric Acid Reactive Substance (TBARS)

Each meat sample (5 g) from the thigh muscles of each replicate was homogenized in 15 ml of distilled water. Sample homogenate (5 ml) was transferred to a test tube and lipid oxidation was determined as the 2-thiobarbituric acid-reactive substance (TBARS) value by methods of Ahn *et al*. (1999). Lipid oxidation was reported as milligrams of malondialdehyde per kilogram of meat (Jang *et al*., 2007).

Sensory Evaluation

Each meat sample (10 g) from the thigh muscle of each replicate was used. Seven experienced trained panelists awarded scores using a 9-point Hedonic scale of (1 = Dislike extremely, 2 = Dislike very much, 3 = Dislike moderately, 4 = Dislike slightly, 5 = Intermediate, 6 = Like slightly, 7 = Like moderately, 8 = Like very much, 9 = Like extremely (Sanwo *et al*., 2013).

Statistical Design and Model

Data obtained were subjected to one way analysis of variance and analyzed using the general linear model procedure of SPSS (2011) version 20. Treatment means with significant difference at $p<0.05$ were compared using Duncan Multiple Range Test (DMRT) of the statistical package.

RESULTS

Proximate Composition of Test Ingredients

Table 2 showed results of proximate composition of the test ingredients. Turmeric contains 7.44% protein, 2.87% ether extract, 7.76% ash, 59.85% nitrogen free extract and 15.6% moisture. It also contain 453.26 mg/kg calcium and 1241.92 mg/kg phosphorus, while cayenne pepper contains crude protein (13.99%), fat (14.30%), ash (5.89%), carbohydrates (31.15%), moisture (11.6%), calcium (747.37 mg/kg) and 1918.93 mg/kg of phosphorus.

Table 2: Proximate Composition of Turmeric Powder and Cayenne Pepper powder (100% DM basis)

Proximate Analysis	Turmeric (*Curcuma longa*) Rhizome Powder	Cayenne pepper (*Capsicum frutescens*)
Crude Protein (%)	7.44	13.99
Ether extract (%)	2.87	14.30
Crude fibre (%)	6.48	23.07
Crude Ash (%)	7.76	5.89
Nitrogen Free Extract (%)	59.85	31.15
Moisture (%)	15.60	11.60
Calcium (mg/kg)	453.26	747.37
Phosphorus (mg/kg)	1241.92	1918.93

DM: Dry Matter

Effect of Dietary Turmeric Powder and Cayenne Pepper Powder on Broiler Chickens Meat Composition

Proximate analysis of broiler chicken thigh meat fed dietary inclusions is presented in Table 3. Significant (p<0.05) differences were seen in moisture, ash and crude protein values of the meat. Thigh sample of chickens fed 2 g/kg dietary cayenne pepper had the highest moisture value of 78.04%, as opposed to the basal group with the least value of 74.15%. Highest (p<0.05) percentage of ash was found in meat of birds fed diets of 2 g/kg tur + 1 g/kg cay (0.81%) and 1 g/kg cay (0.79%), while the least value was seen in meat sample of chickens fed 2 g/kg cayenne addition (0.66). The basal group had highest (p<0.05) crude protein content with a protein value of 21.96%, compared to the 19.11% of birds fed 2 g/kg dietary cayenne pepper.

Effect of Dietary Treatments on Cook Loss, Refrigeration Loss, Water Absorptive Power and pH of Broiler Chicken Thigh Meat

Results obtained from determination of cook loss, refrigeration loss, water absorptive power (WAP) and pH of broiler chicken meat fed dietary treatments are presented in Table 4. Significant differences (p<0.05) were observed across treatments for final weight loss and percentages among treatment groups. Final weight of cooked broiler meat samples was highest in birds fed the basal diet (40.82 g), which led to the lowest (p<0.05) cook loss value of 9.19 g as opposed to the highest (p<0.05) cook loss values of 13.21 and 13.10 g respectively. High cook loss (13.21 and 13.10 g) in percentage translates to 26.41 and 26.21 % in meat sample of groups fed 2 g/kg cayenne pepper and 4 g/kg tur + 2 g/kg cay dietary treatments. Similar to the cook loss trend above, refrigeration loss determined for thigh meat samples was lowest in samples of birds fed the basal diet and 2 g/kg dietary cayenne power, with loss values of 0.33 g and 0.74 g respectively, while highest (p<0.05) refrigeration loss values was seen in sample of chickens fed dietary 2 g/kg tur + 1 g/kg cay powder (1.52 g, 3.04%).

Significant (p<0.05) difference was recorded for meat pH of chickens fed dietary treatments. Highest (p<0.05) meat pH values (6.75 and 6.85) were recorded for birds fed 2 g/kg tur + 2 g/kg cay and 4 g/kg tur + 2 g/kg cay diets respectively, which were similar statistically to values recorded for groups fed 2 g/kg turmeric, 4 g/kg turmeric and 2 g/kg cayenne pepper (6.45 – 6.55). Other groups had significantly (p<0.05) lower pH values which ranged from 6.25 – 6.3.

Table 3: Proximate Analysis of Broiler Chicken Meat fed Dietary Treatments

Parameters (%)	Basal diet	B+200t	B+400t	B+100c	B+200c	B+200t+100c	B+400t+100c	B+200t+200c	B+400t+200c	SEM
Moisture	74.75^{b}	76.89^{ab}	76.54^{ab}	75.43^{ab}	78.04^{a}	75.32^{ab}	76.68^{ab}	77.03^{ab}	76.78^{ab}	0.81
Ether extract	2.46	2.28	2.28	2.41	2.14	2.50	2.25	2.21	2.26	0.10
Ash	0.78^{ab}	0.71^{ab}	0.71^{ab}	0.79^{a}	0.66^{b}	0.80^{a}	0.73^{ab}	0.73^{ab}	0.70^{ab}	0.03
Crude Fibre	0.07	0.03	0.03	0.02	0.07	0.04	0.07	0.07	0.08	0.02
Crude protein	21.96^{a}	20.10^{ab}	20.46^{ab}	21.36^{ab}	19.11^{b}	21.44^{ab}	20.28^{ab}	19.97^{ab}	20.20^{ab}	0.71

$^{a, b,}$ Means in the same row with different superscripts differ significantly ($p<0.05$)
c - Cayenne Pepper Powder. t - Turmeric Rhizome Powder

Table 4: Effect of Dietary Treatments on Cook Loss, Refrigeration Loss, WAP and pH of Broiler Chicken Thigh Meat

Parameters	Basal (B)	B+200t	B+400t	B+100c	B+200c	B+200t+100c	B+400t+100c	B+200t+200c	B+400t+200c	SEM
Cook loss %										
Initial Weight (g)	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	0.21
Final Weight (g)	40.82^{a}	40.24^{ab}	38.80^{abc}	39.43^{abc}	36.80^{c}	38.08^{abc}	39.05^{abc}	37.80^{bc}	36.91^{c}	0.84
Cook Loss (g)	9.19^{c}	9.76^{bc}	11.20^{abc}	10.73^{abc}	13.21^{a}	11.92^{abc}	10.96^{abc}	12.51^{ab}	13.10^{a}	0.80
% Cook loss	18.37^{c}	19.51^{bc}	21.68^{abc}	21.40^{abc}	26.41^{a}	23.88^{abc}	21.91^{abc}	24.90^{ab}	26.20^{a}	1.66
Refrigerated Loss of Thigh Meat										
Initial Weight (g)	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	0.00
Final Weight (g)	49.66^{a}	49.32^{ab}	49.13^{ab}	49.01^{ab}	49.63^{a}	48.49^{b}	49.44^{ab}	49.23^{ab}	49.31^{ab}	0.31
Refrigeration Loss (g)	0.33^{b}	0.69^{ab}	0.88^{ab}	0.99^{ab}	0.37^{b}	1.52^{a}	0.57^{ab}	0.78^{ab}	0.69^{ab}	0.32
% Refrigera-tion Loss	0.69^{b}	1.06^{ab}	1.75^{ab}	1.99^{ab}	0.74^{b}	3.04^{a}	1.12^{ab}	1.55^{ab}	1.38^{ab}	0.61
Water Absorptive Power and pH of Thigh Meat										
Initial Weight of meat (g)	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	0.00
Final Weight of meat (g)	3.3	3.5	3.5	3.45	3.25	3.25	3.4	3.4	3.35	0.08
Water Absorp-tive Power (g)	0.3	0.5	0.5	0.45	0.25	0.25	0.4	0.4	0.35	0.08
pH	6.25^{b}	6.5^{ab}	6.55^{ab}	6.3^{b}	6.45^{ab}	6.3^{b}	6.3^{b}	6.85^{a}	6.75^{a}	0.15

$^{a, b, c}$ Means with the same superscript differ significantly ($p<0.05$)

Meat Lipid Profile of Broiler Chickens fed Dietary Treatments

Results obtained from feeding dietary additives on lipid profile and malondialdehyde content of broiler chickens meat is presented in Table 5. All lipid parameters determined were significantly (p<0.05) influenced by dietary inclusions. Total cholesterol value ranged from 81.50-97.00 mg/dl across treatment groups. Meat cholesterol in chickens fed dietary 4 g/kg tur (96.50 mg/dl) and 4 g/kg tur + 1 g/kg cay (97.00 mg/dl) was significantly (p<0.05) higher than the 87.00 mg/dl and 81.50 mg/dl cholesterol content recorded for groups fed dietary 2 g/kg tur + 2 g/kg cay and the basal diet respectively. Triglyceride content of breast meat lipid ranged from 76.50-92.00 mg/dl. Treatment groups fed cayenne pepper at 2 g/kg addition had least (p>0.05) triglyceride value of 76.00 mg/dl, compared to the highest values of 92.00 and 90.00 mg/dl noted in chickens fed 2 and 4 g/kg dietary turmeric respectively. High density lipoprotein was high (p<0.05) in birds fed the basal diet and additives of 2 g/kg turmeric, 2 g/kg cayenne pepper, 2 g/kg tur + 1 g/kg cay and 2 g/kg + 2 g/kg with values ranging from 44.50 – 54.50 mg/dl, while the least value of 40 mg/dl was seen in treatment groups fed 2 g/kg dietary turmeric. Birds fed 4 g/kg turmeric had the highest (p<0.05) low density lipoprotein value of 24.50mg/dl, while least values were recorded for groups fed 2 g/kg tur + 2 g/kg cay (19.75 mg/dl) and 4 g/kg tur + 1 g/kg cay (20.10 mg/dl) diets.

Effect of Dietary inclusion of Turmeric Powder and Cayenne Pepper Powder on Sensory Parameters of Broiler Chicken Meat

The result of sensory evaluation of broiler chickens fed dietary treatments is presented in Table 6. Significant (p<0.05) differences were observed among sensory parameters of broiler chickens fed dietary treatment. Juiciness, meat flavour, saltiness and overall flavour of meat were significantly (p<0.05) influenced by diets fed. Juiciness score of meat sample of birds fed the basal diet (6.65), turmeric as single inclusion at 2 and 4 g/kg (6.72, 6.43) and cayenne at 1 g/kg (6.14) had higher values than the 4.43 score of treatment groups fed dietary 2 g/kg tur + 1 g/kg cay. Turmeric powder dietary addition at 2 and 4 g/kg had higher meat flavour score of 6.57 and 6.64 than samples of birds fed 2 g/kg tur + 2 g/kg cay, which had least (p>0.05) score of 5.50. Saltiness score (3.93; 4.00) were low (p>0.05) in meat sample of treatments groups fed dietary 2 g/kg cay, and 2 and 4 g/kg turmeric powder. Overall flavour score was highest (p<0.05) in groups fed the basal diet (6.14) and diet containing 1 g/kg cayenne pepper (6.21).

Table 5: Effect of Dietary Turmeric Powder and Cayenne Pepper Powder on Lipid Profile and MDA Content of Broiler Chickens Meat

Parameters	Basal (C)	B+200t	B+400t	B+100c	B+200c	B+200t+100c	B+400t+100c	B+200t+200c	B+400t+200c	SEM
Total Chol. (mg/dl)	81.50^{c}	89.50^{ab}	96.50^{a}	91.50^{ab}	94.00^{ab}	91.00^{ab}	97.00^{a}	87.00^{bc}	95.00^{ab}	2.36
Triglyceride (mg/dl)	76.50^{bc}	92.00^{a}	90.00^{a}	81.00^{bc}	76.00^{c}	78.50^{bc}	80.50^{ab}	77.00^{bc}	85.50^{ab}	2.65
HDL (mg/dl)	52.00^{a}	44.50^{a}	40.00^{c}	48.50^{ab}	54.50^{a}	52.00^{a}	46.50^{ab}	53.00^{a}	45.50^{ab}	3.30
LDL (mg/dl)	20.90^{ab}	22.20^{ab}	24.50^{a}	22.55^{ab}	20.50^{b}	20.10^{b}	21.30^{ab}	19.75^{b}	22.70^{ab}	0.95
TBARS (MDA/ g tissue)	0.035^{b}	0.022^{e}	0.034^{bc}	0.029^{d}	0.017^{f}	0.021^{e}	0.032^{c}	0.029^{d}	0.041^{a}	0.01

$^{a, b, c, d, e, f,}$ Means in the same row with different superscripts differ significantly ($p<0.05$)c - Cayenne Pepper Powder;: t- Turmeric Rhizome Powder; Total Chol - Total cholesterol HDL – High Density Lipoprotein; LDL – Low Density Lipoprotein; mg/dl – milligram per diluents; MDA – Malondialdehyde per gram tissue

Table 6: Effect of Feeding Dietary Turmeric Powder and Cayenne Pepper Powder on Sensory Parameters of Broiler Meat

Parameters	Basal (B)	B+200t	B+400t	B+100c	B+200c	B+200t+100c	B+400t+100c	B+200t+200c	B+400t+200c	SEM
Colour	6.50	5.64	5.93	6.43	5.65	6.15	5.50	5.59	5.43	0.36
Juiciness	6.65^{a}	6.72^{a}	6.43^{a}	6.14^{a}	5.65^{ab}	4.43^{b}	5.50^{ab}	5.87^{ab}	5.36^{ab}	0.46
Meat Flavour	6.28^{ab}	6.57^{a}	6.64^{a}	6.35^{ab}	5.79^{ab}	5.86^{ab}	5.93^{ab}	5.50^{b}	5.71^{ab}	0.30
Tenderness	6.86	6.14	5.70	5.07	5.00	5.21	5.50	6.36	5.22	0.94
Saltiness	4.57^{ab}	4.00^{b}	4.00^{b}	3.93^{b}	5.00^{a}	4.29^{ab}	5.00^{a}	5.07^{a}	5.07^{a}	0.28
Overall Flavour	6.14^{a}	5.93^{ab}	4.71^{b}	6.21^{a}	5.72^{ab}	5.15^{ab}	5.50^{ab}	5.15^{ab}	4.86^{ab}	0.40
Overall Accept-ability	6.21	6.14	6.29	6.22	5.44	5.44	5.43	5.00	5.29	0.33

a, b, c Means in the same row with different superscripts differ significantly ($p<0.05$)
Cay - Cayenne Pepper Powder; Tur - Turmeric Rhizome Powder

DISCUSSION

Moisture content of turmeric in this study (15.60%) show slight variation from the 13.10% value reported by Chattopadhyay *et al*. (2004). Duration of drying the rhizomes and prevalent humidity during processing may have influence on moisture value. Crude protein content of turmeric rhizome was slightly lower than the 7.83% reported by USDA (2009), but higher than the 6.3% reported by Chattopadhyay *et al*. (2004). Soil condition may have had influence on protein content of plants with particular reference to soil nitrogen content. The duration and season of drying rhizomes may have led to variation in protein value. Ether extract value from this experiment (2.87) was less than the 5.1% of Chattopadhyay *et al.* (2004) and 9.88% of USDA (2009), while fibre value of 21% is higher than 6.48% observed in this study. Crude protein content in cayenne pepper (13.99%) was higher than the 12.01% of USDA (2009). According to Idowuagida (2010), the response of plants to climate depends on the physiological makeup of the variety cultivated. The variety used in this experiment (Bawa) is locally available under tropical condition. Additionally, ether extract and crude fibre values (14.3, 23.07 %) were lower than values (17.27%, 27.2%) provided by USDA (2009). Cultivar type, sunlight and rainfall pattern may be responsible for such variations.

Meat moisture, ash and crude protein were significant in value. Since water is a component of protein (but not fat), a leaner cut will contain slightly more water on a per weight basis (USDA, 2011). The long hydrocarbon chain at capsaicin's tail as reported by Baboota *et al*. (2014) allows it to bind very strongly with its lipoprotein receptor which allows the molecule to slip through lipid-rich cell membranes, making the burn of triglycerides and fatty acids pervasive and persistent in tissues, thereby rendering more space for water in meat. The basal group however had the highest meat dry matter and crude protein. Dietary composition of feed significantly influence loss values in broiler meat samples. Chickens fed no dietary additive had the least loss. All meat samples of birds fed dietary inclusions recorded elevated loss values over the basal group. This possibly accounts for better protein and dry matter content in meat sample of chickens fed the basal diet. The percentage of naturally occurring water in meat varies with the type of muscle, the kind of meat, the season of the year, and the pH of the meat (USDA, 2011).

Meat with high shrinkage and loss as a result of more movement of moisture from muscle cells will eventually give low meat weight and quality due to water soluble sarcoplasmic proteins, vitamins and enzymes released. The amount of water bound in muscle cells account for the value of meat to consumers. Chickens fed the basal diet had the least cook loss. According to Bowker and Zhang (2013), there is a relationship between the amount of exudate and protein concentration, with protein solubility a measure of denaturation. Additionally, low cook loss in treatment groups fed the basal diet may also be attributed to the common white adipose tissue storage of fat in interstitial spaces of chicken tissue. Baboota *et al*. (2014) reported that capsaicin modulates hypothalamic satiety associated genes, by inducing the browning genotype, which leads to formation of the brown adipose tissue in the skin. This likely resulted in more pore spaces within muscles of treatment groups fed 2 g/kg cay and 4 g/kg + 2 g/kg diets.

Additionally, low pH value of chickens fed the basal diet possibly had a direct bearing on cook loss. Tissue and cellular integrity is best when moisture loss is low facilitated by closer and tighter muscle bands. Findings have demonstrated that internal hemorrhage and sloughing off of stomach cells eventually resulted in death of experimental male mices fed red chilli, or *Capsicum annuum* (sweet pepper) as dietary additives up to 10% for eight weeks. Also, tissues with increased permeability maintain high levels of calcium, and the capsaicin receptor, known as transient receptor potential channel vanilloid subtype 1 (TRPV1) when activated can cause calcium influx, which can mediate capsaicin related type I oxidative fiber formation (Luo *et al*., 2012). This fiber is loose, and upon cooking possibly allows high loss percentage in the meat of chickens fed 2 g/kg cayenne pepper and 4 g/kg tur + 2 g/kg cay diets. This suggests that capsaicin may also have an effect on nerve connections of fibroblast cells, thereby limiting the synthesis of extracellular matrix and inhibiting collagen proteins in connective tissue.

Muscle pH was influenced by feeding dietary treatments, and this was highest in meat samples of treatment groups fed 2 g/kg tur + 2 kg cay and 4 g/kg tur + 2 g/kg cay diets, but was least in group fed the basal diet. Mead (2000) reported leg muscle pH range of 6.1 – 6.4. High pH can predispose muscles to microbial contamination and spoilage. Kotula and Wang, (1994) posited that genetics, physiology, nutrition, management, and disease, in addition to activities occurring before slaughter, transporting and handling can have direct influence on pH of muscles. Muscle pH within normal range have higher tendency toward product stability. The pH obtained was similar to single as well as combined feed additives of 1 g/kg cayenne pepper. Meat tending towards inner cellular acidity at rigor mortis tends towards greater stability of product, possibly signifying tissue integrity and close band of muscles than those pH tending towards basicity.

Meat samples show significant differences in all lipid parameters of broiler chicken meat determined. Cholesterol can be both good and bad for food consumers. Cholesterol, a component of all animal cells is produced in the liver and essential for cell formation. Abnormally high levels of cholesterol and abnormal proportions of low-density lipoproteins (LDL) and high-density lipoproteins (HDL) are associated with cardiovascular diseases (Muchenje *et al*., 2009). Cholesterol content of meat was significantly elevated as turmeric inclusion increased (4 g/kg turmeric and 4 g/kg tur + 1 g/kg cay diet). Nishiyama *et al*. (2005) reported that curcuminoids, such as curcumin, demethoxycurcumin and bisdemethoxycurcum in turmeric pigments have hypocholesterolemic activities. This contradicts results from this study which show elevated cholesterol values as dietary turmeric fed increased. This possibly point to turmeric powder used not containing sufficient curcuminoids in 4 g/kg dietary turmeric to facilitate cholesterol conversion into bile by the liver. Akram *et al*. (2010) also stated that curcuminoids effect on cholesterol levels may involve cholesterol uptake in the intestines and increased conversion of cholesterol to bile acids in the liver. In the same vein, research demonstrated by Danesheyar *et al*. (2011) showed that at 10 g/kg, turmeric dietary inclusion reduced cholesterol content of broiler meat. Plaque formation is more likely to occur when inflammation levels in the body are elevated, which is why modern studies suggests keeping cholesterol levels lowered or within the recommended range.

Triglyceride values were best suppressed in treatment groups fed 2 g/kg cayenne pepper diet. According to Allen and Bredford (2006), the degree of fat mobilization is affected by changes in plasma insulin concentration and sensitivity of tissues to insulin. Plasma insulin concentration signals tissues to synthesize fat if elevated or to mobilize fat if lowered. This possibly suggests how turmeric stimulated lipid production and deposition in groups fed 2 and 4 g/kg turmeric. As reported by Joo *et al*. (2010), capsaicin increases thermogenesis through enhancement of catecholamine secretion from the adrenal medulla. Capsaicin's heat potential may temporarily increase thermogenesis in the body by burning fuel such as fat to generate heat, with beneficial impacts on body metabolism and fat-burning potential. Additiionally, research conducted by Baboota *et al*. (2013) show how the fatty tail of capsaicin allows the molecule to slip through lipid-rich cell membranes, making the burn more pervasive and persistent. Cayenne cleans the arteries as well, and can help to rid the body of triglycerides by dissolving fibrinogen, a blood clot substance associated with plaque formation in the artery wall.. Activity on cayenne pepper from present findings agree with the study of Akbarian *et al*., (2012) that triglycerides significantly ($p<0.05$) reduced in birds fed diet containing 1 g/kg black pepper. This possibly explains how birds fed 2 g/kg cayenne pepper had reduced meat triglyceride. High triglyceride has been found to be associated with coronary heart disease, myocardial infarction and stroke in humans.

Liver cells take out LDL cholesterol out of the bloodstream and are therefore protected from fatty acid damage. Reverse cholesterol transport is a pathway for plaque reduction and the key mediator in the process is HDL. The apo-lipoproteins within the HDL particles suppress cholesterol within the arterial plaque, thereby reducing the amount of overall plaque on the artery wall. This assists the liver to makes more bile salts which carry excess LDL out of the body into the waste matter of the large intestine, signaling more production of HDL cholesterol. Treatments groups fed 2 g/kg cayenne pepper diet, 2 g/kg turmeric and 2 g/kg tur + 1 g/kg cay diets had significantly high HDL and low LDL cholesterol values. In facilitating liver function as stated above, curcumin and capsaicin may possibly stop the progress of fatty liver and enhances cardiovascular health (Joo *et al*., 2010). Additionally, according to Muchenje *et al*. (2009) a strong relationship exists between low density lipoprotein (LDL) cholesterol levels and HDL cholesterol which have inverse relationship with the risk of cardiovascular diseases. Result from present findings show a link between low triglyceride, high HDL and low LDL in treatment groups mentioned above.

Though storage time was not observed, thiobarbituric acid reactive substances (TBARS) values obtained were within acceptable range of 0.2 described as good meat quality (frigg 1992). Treatment groups fed dietary 2 g/kg cayenne pepper had the best ($p<0.05$) value, indicating potential storage length of chicken meat of this group. Mulla (2002) posited that high TBARS value is caused by fat oxidation and high mono and poly unsaturated fat content. Bartov and Frigg (1992) also reported that oxidative stability was best in tissues of broiler chickens fed antioxidant continuously. Capsaicin, the most active compound in pepper is an antioxidant that can retards microbial storage in meat by inducing lower production of lipid within the animals, particularly membrane structures. Similarly, Sun *et al*. (2007) reported that bell pepper prevented the oxidation of essential fatty acids. This was further explained by Oboh and Rocha, (2008) who demonstrated how antioxidant ability of bell pepper can have protective effects on the brain cells. Hence, capsaicin present in cayenne pepper could have actively prevented oxidation of the essential fats within the brain cells that are considered necessary for optimal brain function. Similarly, Buckley *et al* (1995) stated that feeding poultry a higher level of natural dietary antioxidants provides the poultry industry with a simple method for improving oxidative stability, sensory quality, shelf life, and acceptability of poultry meat. Capsaicin in cayenne pepper most suppressed the formation of malondialdehyde in meat sample of birds fed dietary 2 g/kg cayenne pepper.

Sensory parameters were significantly influenced by feed composition. USDA (2011) reported that fat in meat is found both between muscles and within muscles, and amount of meat fats in both locations can stimulate meat juiciness, contributing to juiciness score of treatment groups fed the basal diet, 1 and 2 g/kg turmeric and 1 g/kg cayenne pepper diet. Flavour however a complex sensation that involves aroma was high ($p<0.05$) in groups fed 2 and 4 g/kg dietary turmeric, which may be explained by result obtained from determined analysis of meat triglyceride, with these groups having highest meat triglyceride content. Fat is very important from a sensory aspect since it is a source of many aromatic substances affecting the meat taste. Additionally, curcumin, an aromantic compound in turmeric have hydrocarbon tails, and adding it into the basal diet may have facilitated deposition of these compounds in tissues. Meat saltiness can be alluded to the content of sodium salt in meat samples, and result obtained show that chickens fed dietary cayenne pepper at 2 g/kg singly, its combination with 2 g/kg turmeric powder, and meat from groups fed 4 g/kg tur + 1 g/kg cay as well as 4 g/kg tur + 2 g/kg cay, possibly had high sodium salt than meat samples of other treatment groups. Miettinen (2004) summarized mastication, saliva, diffusion, binding, and temperature's effect of food during eating as well as cross modal and multimodal effects of taste and olfaction to a large degree contribute to overall flavour, which was subject to the view of the panelists. Chickens fed the basal diet and 1 g/kg cayenne pepper had high overall flavor scores and as explained by Delwiche (2004) it is not only taste and olfaction that lead to a flavour perception but other attributes such as colour (Johnson, 2006), and meat texture or thickness (Cook *et al*., 2003) This likely suggest why these treatment groups had overall flavor score.

CONCLUSION

It was evident in the study that the dietary inclusions of the test ingredients limited lipid oxidation, thus improved storage duration and meat flavor.

Acknowledgement

I thank all Staffs, the chief technologist and laboratory attendant of the Department of Animal Production and Health, College of Animal Science and Livestock Production, Federal University of Agriculture, Abeokuta for their support throughout the duration of research.

Funding Report

No external funding was provided

REFERENCES

AOAC (Association of Official Analytical Chemists) 2005.*Official Methods of Analysis.*18th edition. AOAC. International, Arlington V. A, USA; pp. 30-31(Chapter 4))

Akbarian, A., Golian, A., Kermanshashi, H., Gilani, H., Moradi, S. 2012. Influence of turmeric rhizome powder and black pepper on blood constituents and performance of broiler chickens. *African Journal of Biotechnology* 11: 8608-8611

Akram, M., Hahab-uddin, A., Ahmed, K., Usmanghani, A., Mohiuddin, E. Asif, M. 2010. *Curcuma Longa* and Curcumin: A Review Article. *Roman Journal of biology. – Plant Biology* 55(2): 65–70.

Allen, M. S., Bradford. B. 2006. From the liver to the brain: Increasing feed intake in transition cows. Pages 115-124 in Proc. 68th Meeting of the Cornell Nutrition Conference for Feed Manufacturers, Department of Animal Science, Cornell University, Ithaca, New York.

Baboota, R. K., Singh, D. P., Sarma, S. M., Kaur, J., Rajat, S., Ranveet, K. 2014. Capsaicin-induced transcriptional changes in hypothalamus and alterations in gut microbial count in high fat diet fed mice. *The Journal of Nuritional Biochemistry*: DOI: 10.1016/j.jnutbio.2014.04.004

Castillo,C., Hernández, J., I. Valverde *et al*., 2006. "Plasma malonaldehyde (MDA) and total antioxidant status (TAS) during lactation in dairy cows," *Research in Veterinary Science*, 80 (2): 133–139

Cross, A. J., Ferrucci, L. M., Risch, A., Graubard, B. I., Ward, M. H., Park, Y., Hollenbeck,A. R., Schatzkin, A., Sinha, R. 2010. A large prospective study of meat consumption and colou-rectal cancer risk: An investigation of potential mechanisms underlying this association. *Cancer Research*15: 2406–2414.

Daneshyar, M., Alizadeh, G., Sabzi M., Bayeghra, F., Farhangpajhoh F, Aghaei, M 2011. Effects of dietary turmeric supplementation on plasma lipoproteins, meat quality and fatty acid composition in broilers. *South African Journal of Animal Science* 41: 420-428.

Descalzo, A. M., Sancho, A. M. 2008. "A review of natural antioxidants and their effects on oxidative status, odor and quality of fresh beef produced in Argentina," Meat Science, 79 (3) 423–436.

Estevez, M., D. Morcuende, S. Ventanas, 2009. Handbook of Processed Meat and Poultry Analysis: determination of oxydation. CRC Press. USA.

Feltwell, R., Fox, S. 1979. Practical poultry feeding. English Language Book Society Great Britain, 92-105

Ferguson, L. R. 2010. Meat and cancer. *Meat Science* 84: 308–313.

Folch, J., Lees, M., Sloane-Stanley, G. H. 1957. A simple method for the isolation and purification of total lipids from animal tissues. *Journal of Biology Chemistry* 233: 311- 320.

Frigg, M. 1992. Research experiences with vitamin E for poultry meat quality. Hoffmann-La Roche Ltd., Basel, Switzerland, pp.2.

FUNAAB, 2016. Policy on research of the Federal University of Agriculture, Abeokuta, Nigeria. http://www.unaab.edu.ng (07/04/2016)

Google Earth Pro 6.2.1.6014 (beta). (October 5, 2011). Niagara Region, ON Canada. 43° 02' 26.22"N, 79° 13' 50.11"W, Eye alt 36 mi. Borders and labels; places layers. NOAA, Digital Globe 2013. <http://www.google.com/earth/index.html> (Accessed April 1, 2013).

Gurikar, A.M., V. Lakshmanan, Y.P. Gadekar, B.D. Sharma and A.S.R. Anjaneyulu, 2014. Effect of meat chunk size, massaging time and cooking time on quality of restructured pork blocks. J. Food Sci. Technol., 51: 1363-1369.

Idowu- Agida, O. O., Adetimirin, V. O., Nwanguma, E. I., Makinde, A. A. 2010. Effects of Seasonal variability on the Performance of Long Cayenne Pepper Collected from South-western Nigeria. *Researcher*: 2 (10):85-92 1553-9865.

Jang, I. S., Ko, Y. H., Kang, S. Y., Lee, C. Y. 2007. Effect of a commercial essential oil on growth performance, digestive enzyme activity and intestinal microflora population in broiler chickens. *Animal Feed Science Technology* 134: 304-315

Joo, J., Kim, D. H., Choi, J. W., Yun, J. W. 2010. Capsaicin increases thermogenesis through enhancement of catecholamine secretion from the adrenal medulla. *IProteome Research* 9(6):2977-87

Kang, J. H., Goto, T., Han, I. S., Kawada, T., Kim, Y. M., Yu, R. 2010. Dietary capsaicin reduces obesity-induced insulin resistance and hepatic steatosis in obese mice fed a high-fat diet. *Obesity Silver Spring* 4:780-7.

Kotula, K. L., Wang, Y. 1994. Characterization of broiler meat quality factors as influenced by feed withdrawal time. *Journal of Applied Poultry Research* 3: 103.

Kim, Y. K., Jin S. K., Yang, H. S. 2009. Effect of dietary garlic bulb and husk on the physicochemical properties of chicken meat. *Poultry Science* 88: 398-405

Mardalena, L., Warly, E. Nurdin, E.,Rusmana, W. S.,N. Farizal, 2011."Milk quality of dairy goat by giving feed supplements as antioxidant source," *Journal of the Indonesian Tropical Animal Agriculture*, 36: 205–211

Mead, G. C. 2000. Fresh and further – processed poultry In: The Microbiological Safety and Quality of Food. Edited B. M., Lund, Aspen Publisher, 445- 471.

Medvedeva, N. V., Andreenkov, V. A, Morozkin, A. D., Sergeeva, E. A., Alu, M. 2003. Inhibition of oxidation of human blood low density lipoproteins by carotenoids frompaprika). *Biomedicine* Khim. 49 (2): 191-200.

Micha, R., Wallace, S. K. and Mozaffarian, D. 2010. Red and processed meat consumption and risk of incident coronary heart disease, stroke and diabetes mellitus. A systematic review and meta-analysis. *Circulation*, 121: 2271–2283.

Min, B., K. C. Nam, J. Cordray., D. U. Ahn. 2008. Endogenousfactors affecting oxidative stabilityof beef loin, pork loin, andchicken breast and thigh meats. J. Food Sci. 73:C439–C446

Muchenje, V., Dzama, K., Chimonyo, M., Strydom, P. E., Hugo, A. and Raats,

J. G. 2009. Some biochemical aspects pertaining to beef eating quality and consumer health: A review. *Food Chemistry* 112: 279-289.

Mulla, Z. S. 2002. Studies on the onset of warmed over flavour in ground beef products and the use of M – S based electronic nose in differentiating beef products. Thesis, the Ohio state University.

NRC, National Research Council 1994. Nutrient Requirements of Poultry. 9th revised ed. National Academy Press, Washington, DC, USA

Oboh, G., Rocha, J. B. 2008. Hot Pepper (*Capsicum* spp.) protects brain from sodium nitroprusside- and quinolinic acid-induced oxidative stress in vitro. *Journal of Medicine and Food* 11: 349-355

Reddy, G.V.B., A.R. Sen, K.S. Reddy, K.K. Reddy, T.M. Rao and N. Kondaiah, 2015. Quality characteristics of restructured mutton slices developed by cold-set binding system. Indian J. Small Rumin., 21: 300-305.

Reddy G.V. B, P.K. Mandal, A.R. Sen, K.S. Reddy. 2015. Developments in Science, Technology, Quality and Constraints of Restructured Meat Products-A Review International *Journal of Meat Science* 5 (1): 14-48, 2015

Ross, J.A., Kasum, C.M., 2007. Dietary flavoids: Bioavailability, metabolic effects and safety. Annual Revision on Nutrition (22) 19-34.

Santarelli, R. L., Vendeuvre, J. L., Naud, N., Taché, S., Guéraud, F., Viau, M., Genot, C., Corpet, D. E., Pierre, F. H. F. 2010. Meat processing and colon carcinogenesis: Cooked nitrite-treated and oxidized high-heme cured meat promotes mucin-depleted foci in rats. *Cancer Preview Research* 3: 852–864.

Sanwo, K. A., Ibrahim, K., Iposu, S.O., Adegbite, J. A. 2012. Effects of substituting wheat flour with plantain flour in beef sausage production. *The Pacific Journal of Science and Technology* 14 (11): 473-478.

Skibsted, L. H. 2011. Nitric oxide and quality and safety of musclebased foods. Nitric Oxide 24:176–183.

Snitker, S., Fujishima, Y., Shen, H., Ott, S., Pi-Sunyer, X., Furuhata, Y., Takahashi, M. 2009. Effects of novel capsinoid treatment on fatness and energy metabolism in humans: possible pharmacogenetic implications. *The American Journal of Clinical Nutrition* 89(1): 45-50.

Statistical Package for Social Sciences, 2011. IBM Corporation Released 2011. IBM SPSS, Statistics for Windows, Version 20.0. Armonk, New York: IBM, CorporationSPSS.

Sun, T., Xu, Z, Wu, C. T., Janes, M., Prinyawiwatkul W., No, H. K. 2007. Antioxidant activities of different coloured sweet bell peppers (*Capsicum annuum*L.). *Journal of Food Science* 72: S98-102.

Surai, P.F., 2002. Natural antioxidants in avian nutrition and reproduction. Nottingham University Press. Nottingham, UK.

USDA, 2009. *"Capsicum L." Germplasm*. Resources Information Network. United States Department of Agriculture. 1 September 2009. Retrieved

USDA, 2011. Water in Meat and Poultry. Food Safety and Inspection Service. Food Safety Education, Safe Food Handling: published 13- 05- 2011.

Velasco, V., Williams, P. 2011. "Improving meat quality through natural antioxidants," *Chilean Journal of Agricultural Research*, 71: 313–322.

Villaverde, A., V. Parra., M. Estevez. 2014. Oxidative and nitrosative stress induced in myofibrillar proteins by a hydroxylradical-generating system: impact of nitrite and ascorbate. *Journal of Agriculture Food Chemistry* 62:2158–64

Winkel-Shirley, B. 2001. Flavonoid biosynthesis. A colourful model for genetics, biochemistry, cell biology, and biotechnology. *Plant Physics* 126: 485-493.

Wuthi-Udomlert, M., Grisanapan, W., Luanratana, O., Caichompoo, W. 2000. Antifungal activity of *Curcuma longa* grown in Thailand. *Southeast Asian Journal of Tropical Medicine Public Health* 31:178-182.

Wood, J. D., Enser, M., Fisher, A.V., Nute, G.R., Whittington, F.M. & Richardson, R.I., 2003. Effects of diets on fatty acids and meat quality. Options Méditerranéennes, Series A. 67, 133-141

Wood, J. V., Enser, M., Fisher, A.V., Nute, G. R., Sheard, P. R., Richardson, R. I., Hughes, S. I., Whittington, F. M., 2008. Fat deposition, fatty acid composition and meat quality: A review. *Meat Science*, 78: 343-358.

Wuthi-Udomlert, M., Grisanapan, W., Luanratana, O., Caichompoo, W. 2000. Antifungal activity of *Curcuma longa* grown in Thailand. *Southeast Asian Journal of Tropical Medicine Public Health* 31:178-182.

Xiong, Y. L. 1996. Impacts of oxidation on muscle protein functionality. Pages 79-86 of the 49th Annual Proceedings of the Reciprocal Meat Conference. American Meat Science Association, Chicago, ILv

Yarozhenko, F.O., Surai, P.F., Yarozhenko, Y.F., Karadas, F., Sparks, N. H. C. 2004. Theoretical background and commercial application of production of Se enriched chicken. XXII World's Poultry Congress, Istanbul, Turkey 8-13 June, N2 Nutrition and management aspects of quality and safety of meat.

(Manuscript received: 13th October, 2019; accepted: 29th June, 2020).