Advance Journal of Food Science and Technology 2(4): 219-226, 2010
ISSN: 2042-4876
© 2010 Maxwell Scientific Organization, 2010
Submitted Date: July 02, 2010 Accepted Date: July 28, 2010 Published Date: July 30, 2010

Effect of Growth Enhancers on Quality of Chicken Meat During Cold Storage

[1]F.H. Ali and [2]D.A. Zahran
[1]Department of Food Hygiene and Control, Faculty of Veterinary Medicine,
Beni Seuf University, 62511 Beni-Suef, Egypt
[2]Department of Health Radiation Research, National Center for Radiation Research and
Technology (NCRRT), 29 Naser City, Cairo, Egypt

Abstract: This study was conducted to assess the effect of some growth enhancers as dietary onion & garlic (Allium sativum) and vitamin E supplementation with water on the meat quality parameters of broiler chicken. A total of 150 chicks were divided into 3 groups, 50 birds per treatment. The first group was fed control diet, the second group fed control diet supplemented with onion 2% and garlic 2% and the third group fed on control diet with vitamin E mixed with water. Birds were slaughtered at the end of the trial to evaluate pH, moisture content, cooking loss, shear force, instrumental color and fatty acids composition of refrigerated (5±1ºC for 6 days) and frozen (3 and 6 months) samples. There was a significant decrease in the mean pH, shear force, a*- and b*- values and cooking loss in samples from chicken dietary supplemented with onion & garlic, and also in chicken (supplemented) with vitamin E mixed with water compared with the control. The mean moisture contents of chicken samples were not significantly influenced by the used growth enhancers. There was a numeric decrease in total saturated fatty acids (TSF %) and an increase in total unsaturated fatty acids (TUS %) in chicken samples (supplemented) with vitamin E mixed with water than control and which supplemented with onion & garlic. Palmitic was the predominant saturated fatty acid, while oleic was the predominant unsaturated fatty acid. It could be concluded that the supplementation of onion & garlic and vitamin E improved chicken meat quality during refrigerated and frozen storage.

Key words: Chicken, dietary supplementations, meat quality, onion and garlic, vitamin E

INTRODUCTION

Poultry meat offers considerable potential for bridging the gap between supply and demand for animal protein, especially in Africa. In this continent and other less developed nations, the low level supply of animal protein is due to the poor performance of livestock, which has been attributed to factors such as inadequate nutrition, high price and poor quality of feeds and inefficiency in production and distribution in the feed industry (Aletor, 1986; Tewe, 1997). Apart from the inadequate supply and consumption of animal protein, there has been a resurgence of interest in improving the physicochemical and sensory properties of meat, as well as its storage life. In pursuit of improved chicken healthiness and in order to fulfill consumer expectations in relation to food quality, poultry producers more and more commonly apply natural feeding supplements, mainly herbs (Gardzielewska *et al*., 2003). The use of nutritional strategies to improve the quality of meat is a relatively new approach that has emerged at the interface of animal science and food science. It often represents the only technology available to alter the quality of intact muscle, where utilization of exogenous compounds is difficult if not impossible. Nutritional approaches are often more effective than direct addition of the additive to meat since the compound is preferably deposited where it is most needed (Govaris *et al.*, 2004).

Lipid and myoglobin oxidation are major causes of meat quality deterioration during storage (Jensen *et al*., 1998). In addition, different animal species may be classified on the basis of meat sensibility to oxidation in the following order fish, turkey, chicken, pork, beef and lamb (Tichivangana and Morissey, 1985). To ensure optimum quality, it is necessary to consider the entire production chain from farm to fork. Many studies focused on the impact of many dietary supplemental components such as vitamin E on post-mortem meat quality (Jensen *et al.*, 1998; Govaris *et al.*, 2007). Supplementation of vitamin E significantly improved the meat stability against oxidative deterioration in beef (Mitsumoto *et al*., 1993), pork (Phillips *et al.*, 2001) and turkey meat (Guo *et al.*, 2001). Vitamin E cannot be synthesized by animals and therefore its presence in animal tissue reflects the dietary availability. Due to its lipophilic character, the vitamin E absorption is dependent

Corresponding Author: F.H. Ali, Department of Food Hygiene and Control, Faculty of Veterinary Medicine, Beni Seuf University, 62511 Beni-Suef, Egypt

on animal fat digestion and absorption (Wiss *et al.*, 1962). Vitamin E is a membrane-associated antioxidant and dietary vitamin E supplementation highly suppresses lipid oxidation (Morrissey *et al.*, 1998; O'Neill *et al.*, 1999; Ruiz *et al.*, 1999) and delays metmyoglobin formation (Jensen *et al.*, 1998; Faustman *et al.*, 1998). It stabilizes poly-unsaturated fatty acids and cholesterol in muscle against oxidative deterioration. This effect is primarily due to the incorporation of the vitamin E into the sub-cellular membranes, where it maximizes the antioxidant capacity (Monahan *et al.*, 1994; Buckley *et al.*, 1995). It is also believed to suppress the development of Pale Soft and Exudative (PSE) in chicken breast meat thus improving meat functional properties (Olivo *et al.*, 2001).

Garlic (Allium sativum), a herbal supplement have been widely used to maintain and improve health of humans (Freeman and Kodera, 1995), in broiler chicken have been recognized for its strong stimulating effect on the immune system and the very rich aromatic oils enhance digestion of birds (Gardzielewska *et al.*, 2003). The key active ingredient in garlic is a powerful plant chemical called allicin which rapidly decompose to several volatile organo-sulphur compounds with bioactivities (Chang and Cheong, 2008). Garlic is used both as condiment and medicament, anticoagulant, antioxidant, hypo-lipidaemic, antihypertensive, anti-ageing, anti-platelet and heavy metal detoxifier (Agarwal, 1996; Marilynn, 2001). Therefore, trials have evaluated garlic as an alternative of growth promoters in livestock and measured its effects on growth digestability and carcass traits (Bampidis *et al.*, 2005; Tatara *et al.*, 2005). The anti-oxidative influence of garlic in meat becomes more imperative in less developed nations, considering storage problems and increasing use of alternative feed resources without due consideration for meat quality (Onibi *et al.*, 2007). Supplementary garlic for broilers could mediate in getting the bioactive compounds in garlic, through broiler meat into the human food chain, while avoiding the resentment due to its direct consumption.

Therefore, the current study was designed to evaluate the effect of onion & garlic and vitamin E as supplementations on quality parameters of chicken meat.

MATERIALS AND METHODS

Experimental design: A total of 150 Cobb chicks of one day old were bought from a poultry company at El Mansoura Governorate. Chicks were divided into 3 groups (50 each) in separate pens (3.5 m x 1.5 m) in the experimental poultry house at faculty of veterinary Medicine Beni-Suef University. There were 50 birds /pen for a final density of 8 birds/ m^2. Chicks were reared under good hygienic conditions. The diets were formulated to meet or exceed the nutrient requirements. Diets and water were freely eaten and lighting was on for 24 h. First group fed on formulated diet and kept as control. The diet of the second group was supplemented with garlic 2% and onion 2% (commercial dried powder, EL-shrouk Company, Egypt) during the whole rearing period (20 g/ Kg diet).The third group fed the control diet but water was supplemented with vitamin E (AGRI - Vet, Egypt). Each liter of supplement contains $2x10^5$ mg vitamin E. At the end of the experiment; all groups of chickens were separately slaughtered in poultry slaughter plant at Beni-Suef City.

Experimental techniques: Chicken carcasses were transferred to the National Center for Radiation Research and Technology (NCRRT) in ice boxes. The thighs and the breasts were separately dissected from each carcass, placed in sealable polyethylene bags relative to each dietary treatment (control, garlic and onion and vitamin E) and stored either in the refrigerator (5±1ºC) and examined at regular intervals under chilling conditions until spoilage of control (every 3 days) or in the freezer and examined after 3 and 6 months. All skin, subcutaneous fat and visible connective tissue were removed before evaluation for different quality parameters. All evaluations were determined in triplicates.

PH measurement: The pH was measured by directly inserting the electrodes in the breast muscle using a pH meter (Mettler Toledo/ MB 220, UK) in each sample group (Olivo *et al.*, 2001). Analyses were performed in triplicate on refrigerated and frozen samples. The pH meter was daily calibrated with standard buffers of pH 4.0 and 7.0 at 25ºC.

Moisture content: Moisture content of chicken thighs were determined according to the Association Official Analytical Chemists (AOAC, 1990), by drying about 10 g of the sample at 105ºC until a constant weight was recorded.

Cooking loss and shear force: The breast samples of each treated group were oven cooked at 180ºC for 20 min to attain an internal temperature of 70ºC. Samples were left to cool at room temperature then used for the determination of cooking loss and tenderness. Cooking loss of the examined samples were determined, each sample was weighed prior to cooking. Upon completion of cooking, a final weight was obtained and cooking loss % was determined as the differences between the fresh and cooked weight divided by the fresh weight %.

The shear force was then determined using Instron 1195 (England) with a blade (68 mm wide, 72 mm long and 3 mm thick) (Yoon, 2003). The blade advanced 10 mm/min and the pick up strength of the measuring head was 50 Kg with the muscle fibers parallel to the

Table 1: Statistical analysis of PH and moisture content (%) of chicken samples as affected by different growth enhancers during refrigerated and frozen storage

	Storage					
Treatment	0 time	3 days	6 days	3 month	6 month	Mean
	pH					
Control	5.82	6.14	6.36	7.0	7.52	6.57 ± 0.16^{A}
O & G	5.72	5.91	6.24	5.96	6.63	6.09 ± 0.09^{C}
Vitamin E	5.8	5.87	6.24	6.42	6.67	6.20 ± 0.09^{B}
Mean	5.78 ± 0.02^{e}	5.97 ± 0.05^{d}	6.28 ± 0.03^{c}	6.46 ± 0.16^{b}	6.94 ± 0.15^{a}	
LSD of treatment: 0.09	LSD of storage: 0.12					
F-value of, treatment: 63.36, storage: 126.11, treatment* storage: 12.24						
	Moisture content (%)					
Control	75.81	72.93	71.79	72.58	73.45	73.31 ± 0.48^{A}
O & G	73.99	73.47	72.01	70.5	72.12	72.73 ± 0.68^{A}
Vitamin E	74.74	73.99	71.43	70.93	72.56	72.42 ± 0.6^{A}
Mean	74.84 ± 0.57^{ab}	73.46 ± 0.63^{ab}	71.74 ± 0.91^{c}	71.34 ± 0.6^{c}	72.71 ± 0.53^{cb}	
LSD of treatment: 1.61	LSD of storage: 2.08					
F-value of, treatment = 0.78, storage = 4.47 and treatment* storage = 0.30						

O & G: onion & garlic

Mean values with different capital letters within column are significantly different ($p<0.05$)

Mean values with different small letters within row are significantly different ($p<0.05$)

direction of the blade. The results were expressed as kilogram force (Kg f) to shear.

Instrumental color measurements: Instrumental color determinations were made on the surfaces of skinless breast samples using a micro color unit attached to a data station (Brano Lange -Germany) using the standard CIE LAB color system as follows: a-value (redness/green), b-value (yellowness/blue) and L-value (lightness/ darkness,). Color measurements were determined in triplicate on each treatment group. All samples were measured in polyethylene bags. Six readings were taken at various points on each breast in an area free of obvious color defects (over scald, bruises and blood accumulation) (CIE, 1978).

Fatty acids profile: Fat extraction was done as described by Folch *et al.* (1957) using chloroform and methanol (2:1. vol./vol.). For preparing the fatty acids, the total lipids were saponified by boiling under reflux with an excess of dilute aqueous ethanolic alkali. The ether containing the water-soluble hydrolysis products (mainly soap solution and glycerol) was acidified by sulphuric acid to liberate the free fatty acids. The free fatty acids were then extracted with diethylether, recovered, dried over anhydrous sodium sulphate and transformed to their methyl esters for GC-MS analysis (Varso, 1972). Each fatty acid was identified in the form of a methyl ester by comparing the retention times with the standard acquired from Sigma. Fatty acids profile was determined quantitatively using a Gas chromatograph-Mass selective detector Instrument C-MS type HP 6890 Series equipped with innowax - Cross-linked polyethylene glycol column 30 m length; 0.32 µm internal diameter; 0.5 um film thickness. Oven temperature was programmed at 150ºC for 1 min., then elevated to 235ºC with a rate of 17ºC/ min., then raised to 245 with a rate of 1ºC/ min., and hold at 245ºC for 5 min. The carrier gas was Nitrogen (1.5 mL/min), the detector was FID, 270ºC and injector temperature was 260ºC. The identification of fatty acids was based on authentic standards (Sigma). The final results were expressed as relative percentages of the fatty acids identified

Statistical analysis: The samples were collected from chicken dietary supplemented with onion & garlic, vitamin E and control diets and analyzed 5 successive times (3 during chilling and 2 during freezing). The values given in each treatment category are the mean values from three individual samples. Mean ± Standard Errors (SE) were calculated. Two ways analysis of variance (F-test) was done for chicken samples stored in the refrigerator at 4ºC and freezer. Least significant difference (LSD) test ($p<0.05$) was performed on the tested parameters (SAS, 1990).

RESULTS AND DISCUSSION

Table 1 showed the effect of the growth enhancers, onion & garlic and vitamin E on pH and moisture content of chicken meat samples during refrigerated and frozen storage. The results revealed that the muscle pH value ranged from 5.72 (treated samples) to 5.82 (in control sample) at 0-time so that all pH values were within the range expected for normal chicken. However, there was a significant ($p<0.05$) decrease in the mean pH values of samples supplemented with onion & garlic (6.09±0.09) and vitamin E (6.20±0.09) compared with the control (6.57±0.16). Kim *et al.* (2009) reported a linear decrease in pH with increasing levels of dietary garlic. On the contrary, Holden *et al.* (1998) reported an increase in the pH value of meat with garlic supplementation in diets for

Table 2: Statistical analysis of Shear force (Kg f) and cooking loss (%) of chicken samples as affected by different growth enhancers during refrigerated and frozen storage

	Storage					
Treatment	0 time	3 days	6 days	3 month	6 month	Mean
	Shear force (Kg f)					
Control	9.9	8.87	5.7	7.58	8.65	8.54 ± 0.30^{A}
O & G	9.36	8.63	7.69	6.05	6.37	7.22 ± 0.45^{B}
Vitamin E	9.06	6.83	4.83	6.61	5.26	6.52 ± 0.45^{B}
Mean	9.44 ± 0.21^{a}	8.11 ± 0.42^{b}	6.08 ± 0.50^{c}	6.75 ± 0.40^{c}	6.76 ± 0.60^{c}	
LSD of treatment: 0.73	LSD of storage: 0.94					
F-value of, treatmentl = 6.66: , storage = 17.25:, treatment* storage = 1.51						
	Cooking loss (%)					
Control	17.28	20.92	25.72	19.94	20.71	20.91 ± 0.96^{A}
O & G	20.09	20.61	20.8	19.53	19.03	20.09 ± 0.38^{A}
Vitamin E	16.31	18.36	18.58	15.62	17.01	17.18 ± 0.47^{B}
Mean	17.89 0.92^{c}	19.96 0.46^{ab}	21.7 1.34^{a}	18.36 0.83^{cb}	19.05 0.72^{cb}	
LSD of treatment: 1.51	LSD of storage: 1.95					
F-value of, treatment= 14.17, storage= 5.0 and treatment* storage =1.67						

O & G: onion & garlic

Mean values with different capital letters within column are significantly different ($p<0.05$)

Mean values with different small letters within row are significantly different ($p<0.05$)

finishing pigs. Sallam *et al.* (2004) found high pH values in various types of garlic treated chicken sausages compared to the control. By refrigerated and frozen storage there was a significant ($p<0.05$) increase in the mean pH values of all samples. The interaction between treatment and storage was highly significant ($p<0.05$). This finding corresponds to Allen *et al.* (1997).

Although, the mean moisture contents of chicken samples were not significantly ($p>0.05$) influenced by the used dietary supplementations, it significantly decreased ($p<0.05$) by storage. The value of moisture content of the meat did not follow any trend in relation to treatment groups or storage. The interaction between treatment and storage was non significant ($p>0.05$). Similarly, Onibi *et al.* (2009) reported that the moisture content was not significantly ($p>0.05$) influenced by garlic supplementation, muscle type and interaction of the 2 factors.

Table 2 represented the shear force (Kg f) and cooking loss (%) of chicken samples as influenced by different growth enhancers during refrigerated and frozen storage. It was cleared that at zero time, there were minor differences in shear force values of breast meat from the control, onion & garlic and vitamin E fed chicken. Although there were non significant ($p>0.05$) decrease in the mean shear force values of samples from chicken supplemented with vitamin E mixed with water (6.52±0.45 Kg f) compared with those dietary supplemented with onion & garlic (7.22±0.45 Kg f), but this decrease was significant ($p<0.05$) compared with the control (8.54±0.30 Kg f). This significant decrease in shear force values could be attributed to the tenderizing effects of onion & garlic and vitamin E when supplemented to chicken. This held the view of several investigators (Harris *et al.*, 2001; Kim *et al.,* 2009; Li *et al.*, 2009), Also by storage, the mean shear force values significantly decreased ($p<0.05$), thus improving tenderness. The interaction between treatment and storage was highly significant.

Shear force values can be used to determine if meat products vary in texture by measuring the variability in total cutting force. It was highly correlated with overall tenderness of muscle. This value has a highly variable characteristic depending on many intrinsic and extrinsic factors of the meat and on their interactions (Miller, 1994; Destefanis *et al.*, 2008). However, Fletcher (1999) reported no significant effects of color components on breast meat texture, a strong positive relationship between shear force and water holding capacity existed in meat (Joo *et al.*, 1999; Alvarado and Sams, 2000).

Concerning cooking loss, there were significant ($p<0.05$) decrease in the mean cooking loss of samples supplemented with vitamin E mixed with water (17.18±0.47) compared with those dietary supplemented with onion & garlic (20.09±0.38) and control (20.91±0.96). This held with view of Kim *et al.* (2009).

Table 3 tabulated the instrumental color (a*, b* and L* values) of chicken meat as affected by different growth enhancers during refrigerated and frozen storage. In general meat color is perceived by consumers as indicative of freshness in that they discriminate against meat that has turned brown in color. The rate of discoloration in fresh meat is related to the rate of pigment oxidation, oxygen consumption and to the effectiveness of the metmyoglobin reducing system. In fact, discoloration and lipid oxidation are known to be related (O'Keefe and Hood, 1982; Ledward, 1991 and Greene *et al.*, 1971). The mean a* values decreased over time and were significantly ($p<0.05$) different after 6 months of frozen storage (3.23±0.29) compared with the zero-time (4.13±0.11). Although the a* values of breast meat from the control and onion & garlic fed chicken

Table 3: Statistical analysis of Color components (L*, a* and b*) of chicken samples as affected by different growth enhancers during refrigerated and frozen storage.

	Storage				
Treatment	0 time	6 days	3 month	6 month	Mean
	A*				
Control	4.13	3.87	3.48	2.13	3.41±0.25 ^{B}
O & G	4.08	3.56	3.56	3.51	3.68±0.13 ^{B}
Vitamin E	4.18	4.08	4.8	4.05	4.28±0.13 ^{A}
Mean	4.13±0.11 ^{a}	3.84±0.16 ^{a}	3.95±0.26 ^{a}	3.23±0.29 ^{b}	
LSD of treatment: 0.36	LSD of storage: 0.41				
F value of, treatment= 13.33, storage= 7.70 and treatment* storage= 4.44					
	b*				
Control	2.75	3.71	1.6	-1.15	1.71±0.66^{C}
O & G	3.83	3.09	2.13	2.25	2.83±0.31^{B}
Vitamin E	2.66	3.89	4.43	4.5	3.87±0.24^{A}
Mean	3.08±0.28 ^{a}	3.56±0.28^{a}	2.72±0.62^{ab}	1.84±0.85 ^{b}	
LSD of treatment: 0.85		LSD of storage: 0.98			
F-value of, treatment = 13.83, storage = 4.7 and treatment* storage = 6.42					
	L*				
Control	61.12	62.02	54.02	47.47	56.03±2.29 ^{A}
O & G	65.49	60.03	48.27	54.50	57.07±2.01^{A}
Vitamin E	62.65	63.07	50.37	55.25	57.83±1.71^{A}
Mean	63.09±1.09^{a}	61.70±1.26^{a}	52.24±1.69^{b}	50.88±1.45^{b}	
LSD of treatment: 3.15	LSD of storage: 3.64				
F-value of, treatment = 0.70, storage = 25.55 and treatment* storage =2.39					

O & G: onion & garlic

Mean values with different capital letters within column are significantly different ($p<0.05$)

Mean values with different small letters within row are significantly different ($p<0.05$)

decreased, these values were nearly unchanged in vitamin E water supplemented chicken during the refrigerated and freezing period The mean a* value was improved significantly ($p<0.05$) by vitamin E supplementation (4.28±0.13) compared with the control and Onion & Garlic (3.41±0.25 and 3.68±0.13, respectively). The interaction between treatment and storage was highly significantly ($p<0.05$). On the contrary, Zouari *et al.* (2010) and Phillips *et al.* (2001) reported that vitamin E supplementation did not improve the color stability of thigh meat and pork, respectively, the effect of endogenous vitamin E on color quality was more evident in species having higher levels of myoglobin and positive relationship between dietary vitamin E and improved color stability has been clearly demonstrated in beef (Chan *et al*., 1996) and lamb (Guidera *et al.*, 1997). In this respect, Zouari *et al.* (2010) found that dietary vitamin E supplementation increases the endogenous vitamin E level in post-mortem muscles.

Concerning b*-values (yellowness), there was significant ($p<0.05$) differences in the mean values of vitamin E water supplemented (3.87±0.24), onion & garlic (2.83±0.31) fed chicken and control (1.71±0.66). There was a significant ($p<0.05$) decrease in the mean yellowness value from 3.08±0.28 (0-time) to 1.84±0.85 (after 6 months). The interaction between treatment and storage was highly significant.

Although there was no differences ($p>0.05$) in the mean L*-values (lightness) related to different growth enhancers used, but there was a highly significant ($p<0.05$) decrease in the mean values by freezing storage. The interaction between treatment and storage was significant.

In the present study, the relative percentage of the main fatty acids composition obtained by GS-MS analysis to highlight the effect of different growth enhancers on lipids of chicken meat at 0-time and at the end of chilling and freezing (Fig. 1, 2, 3). The ratio of total saturated fatty acids (TSF) to Total Unsaturated Fatty acids (TUF) was calculated to precisely indicate the changes in fatty acids due to the additives. It was cleared from Fig. 1 and 2 that the major fatty acids found were Myristic (14:0), Palmitic (16:0), Stearic (18:0), oleic (18:1) and Linoleic (18:2). Palmitic acid was the predominant saturated fatty acid, while oleic acid was the predominant unsaturated fatty acid. This finding was in agreement with other investigators (Valsta *et al.*, 2005). Fat composition is affected by animal feeding, a fact that is exploited for modification of the meat fatty acid composition, with the best results in poultry (Wood *et al.*, 1999). There was a numeric decrease in Total Saturated Fatty acids (TSF; %) and an increase in Total Unsaturated Fatty acids (TUF; %) in samples with vitamin E mixed with water relative to onion & garlic dietary supplemented and control (Fig. 1 and 2). Approximately 60% of the SFA in US and European diet are obtained from meat (Dupont *et al.*, 1991). Also, USFA are thought to have beneficial effects on health (Belury, 2002). Methods of supplementation have been applied for this purpose in meat products. Therefore, it is conceivable that dietary supplementation with vitamin E to increase concentrations of TUF can

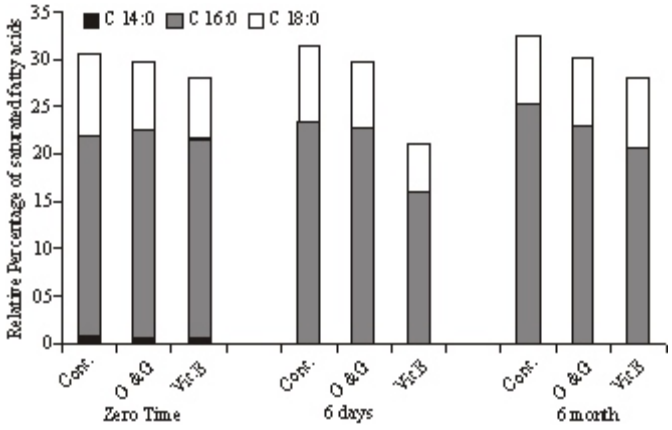

Fig. 1: Relative percentages of saturated fatty acids in chicken samples as affected by different growth enhancers during refrigerated and frozen storage

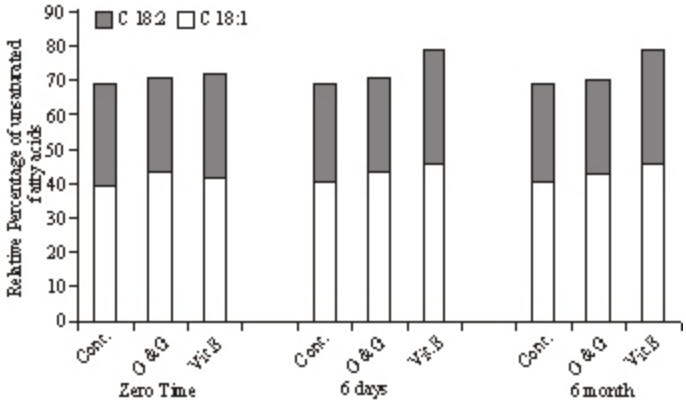

Fig. 2: Relative percentages of unsaturated fatty acids in chicken samples as affected by different growth enhancers during refrigerated and frozen storage

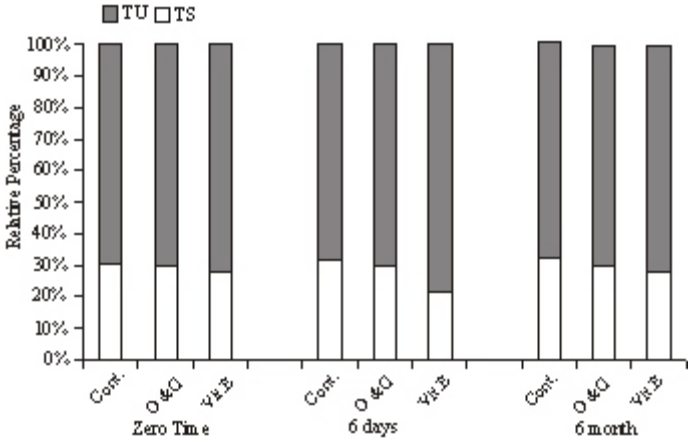

Fig. 3: Relative percentages of total saturated fatty acids: total unsaturated fatty acids in chicken samples as affected by different growth enhancers during refrigerated and frozen storage

have beneficial effects on health because the fatty acids in treated samples are relatively unsaturated. In this respect, Li *et al.* (2009) reported that dietary vitamin E supplementation significantly altered fatty acids composition of breast muscle leading to lower TSF and greater TUF, thus improving meat quality and fatty acid composition, probably by its influence on the expression of genes related to lipid metabolism.

CONCLUSION

It could be concluded that dietary supplementation with onion & garlic and mixing of vitamin E with water during poultry rearing improve quality parameters of chicken meat during chilling and freezing.

REFERENCES

Agarwal, K.C., 1996. Therapeutic action of garlic constituents. Med. Res. Rev., 16: 111-124.

Aletor, V.A., 1986. Some agro-industrial by-products and wastes in livestock feeding, review of prospects and problems. World Rev. Anim. Prod., 22: 36-41.

Allen, C.D., S.M. Russell and D.L. Fletcher, 1997. The relationship of broiler breast meat color and pH to shelf-life and odor development. Poult. Sci., 76: 1042-1046.

Alvarado, C.Z. and A.R. Sams, 2000. The influence of postmortem electrical stimulation on rigor mortis development, calpastatin activity and tenderness in broiler and duck pectoralis. Poult. Sci., 79: 1364-1368.

AOAC, 1990. Official Methods of Analysis, 15th Edn., Association of Official Analytical Chemists Washington D.C., pp: 805-845.

Bampidis, V.A., V. Christodoulou, E. Christaki, P. Florou-Paneri and A.B. Spais, 2005. Effect of dietary garlic bulb and garlic husk supplementation on performance and carcass characteristics of growing lambs. Anim. Feed Sci. Technol., 121: 273-283.

Belury, M.A., 2002. Dietary conjugated linoleic acid in health: physiological effects and mechanisms of action. Ann. Rev. Nutr., 22: 505-531.

Buckley, D.J., P.A. Morrissey and J.I. Gray, 1995. Influence of dietary vitamin E on the oxidative stability and quality of pig meat. J. Anim. Sci., 73: 3122-3130.

Chan, W.K.M., K. Hakkarainen, C. Faustman, D.M. Schaefer and K.K. Scheller, 1996. Dietary vitamin E effect on color stability and sensory assessment of spoilage in three beef muscles. Meat Sci., 42: 387-399.

Chang, K.J. and S.H. Cheong, 2008. Volatile organosulfur and nutrient compounds from garlic by cultivating areas and processing methods. Fed. Am. Soc. Exp. Bio. J., 22: 1108-1112.

CIE, 1978. International Commission on Illumination, Recommendations on Uniform Color Spaces, Color Difference Equations, Psychometric Color Terms. Supplement No. 2 to CIE Publication No. 15 (E-1.3.1) 1971/ (TC-1.3) 1978. Bureau Central de la CIE, Paris, France.

Destefanis, G., A. Brugiapaglia, M.T. Barge and E. Dal Molin, 2008. Relationship between beef consumer tenderness perception and Warner-Bratzler shear force. Meat Sci., 78: 153-156.

Dupont, J., P.J. White and E.B. Feldman, 1991. Saturated and hydrogenated fats in food in relation to health. J. Am. Coll. Nutr., 10: 577-592.

Faustman, C., W.K.M. Chan, D.M. Schaefer and A. Havens, 1998. Beef color update: The role of vitamin E. J. Anim. Sci., 76: 1019-1026.

Fletcher, D.L. 1999. Broiler breast meat color variation, pH and texture. Poult. Sci., 78: 1323-1327.

Folch, J., M. Lees and G.H. Sloane-Stanley, 1957. A simple method for the isolation and purification of total lipids from animal tissues. J. Biol. Chem., 226: 497-507.

Freeman, F. and Y. Kodera, 1995. Garlic chemistry: stability of S- (2-propenyl) 2-propene-1-sulfinothiote (allicin) in blood, solvents and stimulated physiological fluids. J. Agr. Food Sci., 43: 2332-2338.

Gardzielewska, J., K. Pudyszak, T. Majewska, M. Jakubowska and J. Pomianowski, 2003. Effect of plant supplemented feeding on fresh and frozen storage quality of broiler chicken meat. Electron. J. Polish Agric. Univ., 6(2).

Govaris, A., N. Botsoglou, G. Papageorgiou, E. Botsoglou and I. Amvrosiadis, 2004. Dietary versus postmortem use of oregano oil and/ or α-tocopherol in turkeys to inhibit development of lipid oxidation in meat during refrigerated storage. Int. J. Food Sci. Nut., 55: 115-123.

Govaris, A., P. Florou-Paneri, E. Botsoglou, I. Giannenas, I. Amvrosiadis and N. Botsoglou, 2007. The inhibitory potential of feed supplementation with rosemary and/ or α-tocopheryl acetate on microbial growth and lipid oxidation of turkey breast during refrigerated storage. LWT, 40: 331-337.

Greene, B.E., I.M. Hsin and M.W. Zipser, 1971. Retardation of oxidative color changes in raw ground beef. J. Food Sci., 36: 940-942.

Guidera, J., J.P. Kerry, D.J. Buckley, P.B. Lynch and P.A. Morrissey, 1997. The effect of dietary vitamin E supplementation on the quality of fresh and frozen lamb quality. Meat Sci., 45: 33-43.

Guo, Y., Q. Tang, J. Yuan and Z. Jiang, 2001. Effects of supplementation with vitamin E on the performance and the tissue peroxidation of broiler chicks and the stability of thigh meat against oxidative deterioration. Anim. Feed Sci. Technol., 89: 165-173.

Harris, S.E., E. Huff-Lonergan, S.M. Lonergan, W.R. Jones and D. Rankins, 2001. Antioxidant status affects color stability and tenderness of calcium chloride-injected beef. J. Anim. Sci., 79: 666-677.

Holden, P.J., J. Mckean and E. Franzenburg, 1998. Biotechnical for pigs-garlic (ASLR1559). ISU Swine Research Report. Iowa State University, Ames.

Jensen, C., C. Lauridsen and G. Bertelsen, 1998. Dietary vitamin E: Quality and storage stability of pork and poultry. Food Sci. Technol., 9: 62-72.

Joo, S.T., R.G. Kauffman, B.C. Kim and G.B. Park, 1999. The relationship of sarcoplasmic and myofibrillar protein solubility to color and water holding capacity in porcine longissimus muscle. Meat Sci., 52: 291-297.

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

Ledward, D.A., 1991. Color of Raw and Cooked Meat. In: Johnsten, D.E., M.K. Knoght and D.E. Ledward, (Eds.), The Chemistry of Muscle-Based Foods. The Royal Society of Chemistry, Cambridge, UK, pp: 128-144.

Li, W.J., G.P. Zhao, J.L. Chen, M.Q. Zheng and J. Wen, 2009. Influence of dietary vitamin E supplementation on meat quality traits and gene expression related to lipid metabolism in the Beijing-you chicken. Br. Poult. Sci., 50(2): 188-198.

Marilynn, L., 2001. Effect of garlic on blood lipids in particles with coronary heart disease. Am. J. Clin. Nutr., 34: 2100-2103.

Miller, M.S., 1994. Proteins as fat substitutes. In: Hettiarachchy, N.S. and G.R. Ziegler (Ed.), Protein Functionality in Food System. Marcel Dekker Inc., New York, NY.

Mitsumoto, M., R.N. Arnold and R.G. Cassens, 1993. Dietary versus postmortem supplementation of vitamin E on pigment and lipid stability in ground beef. J. Anim. Sci., 71: 12-16.

Monahan, F.J., A. Asghar, J.I. Gray, D.J. Buckley and P.A. Morrissey, 1994. Effect of oxidized dietary lipid and vitamin E on the color stability of pork chops. Meat Sci., 37: 205-215.

Morrissey, P.A., P.J.A. Sheehy, K. Galvin, J.P. Kerry and D.L. Buckley, 1998. Lipid stability in meat and meat products. Meat Sci., 49: 73-86.

O'keefe, S.F. and D.E. Hood, 1982. Biochemical factors influencing metmyoglobin formation on beef from muscles of differing color stability. Meat Sci., 7: 209-228.

Olivo, R., A.L. Soares, E.I. Ida and M. Shimokomaki, 2001. Dietary vitamin E inhibits poultry PSE and improves meat functional properties. J. Food Biochem., 25: 271-283.

O'Neill, L.M., K. Galvin, P.A. Morrisey and D.J. Buckley, 1999. Effect of carnosine, salt and dietary vitamin E on the oxidative stability of chicken meat. Meat Sci., 52: 89-94.

Onibi, G.E., O.E. Adebisi, A.N. Fajemisin and A.V. Adetunji, 2009. Response of broiler chickens in terms of performance and meat quality to garlic (Allium sativum) supplementation. Afr. J. Agric. Res., 4(5): 511-517.

Onibi, G.E., J.O. Agbede, S.T. Afun and V.A. Aletor, 2007. Assessment of the meat quality of broiler chickens fed equi-protein replacement of fish meal with frog meal. Res. Agric. Sci., 1(2): 73-80.

Phillips, A.L., C. Faustman, M.P. Lynch, K.E. Govoni, T.A. Hoagland and S.A. Zinn, 2001. Effect of dietary α-tocopherol supplementation on color and lipid stability in pork. Meat Sci., 58: 389-393.

Ruiz, J.A., A.M. Perez-Vendrell and E. Esteve-Garcia, 1999. Effect of β-carotene and vitamin E on oxidative stability in leg meat of broilers fed supplemental fats. J. Agric. Food Chem., 47: 448-454.

Sallam, K.I., M. Ishioroshi and K. Samejima, 2004. Antioxidant and antimicrobial effects of garlic in chicken sausage. Lebensm. Wiss. Technol., 37: 849-855.

SAS, 1990. SAS Institute, Inc., PO Box 8000, Cary, NC.

Tatara, M.R., E. Sliwa, E. Dudek, K. Mosiewicz and T. Studzinske, 2005. Effect of aged garlic extract and allicin administration to cows during pregnancy and lactation on body weight gain and gastrointestinal tract development of piglets. Bull. Vet. Inst. Pulawy, 49: 349-355.

Tewe, O.O., 1997. Sustainability and Development Paradigm from Nigeria's Livestock Industry. Inaugural Lecture delivered on behalf of Faculty of Agriculture and Forestry, University of Ibadan, Nigeria, pp: 50.

Tichivangana, J.Z. and P.A. Morissey, 1985. Metmyoglobin and inorganic metals as pro-oxidants in raw and cooked muscle systems. Meat Sci., 15: 107-116.

Valsta, L.M., H. Tapanainen and S. Mannisto, 2005. Meat fats in nutrition: A review. Meat Sci., 70: 352-358.

Varso, H.H., 1972. A procedure for isolation and quantitative determination of volatile fatty acids from meat products. J. Food Sci., 37: 136-139.

Wiss, O., R.B. Bunnel and U. Gloor, 1962. Absorption and distribution of vitamin E in the tissue. Vitam. Horm. Applications, 20: 441-456.

Wood, J.D., M. Enser, G.R. Nute, R.I. Richardson and P.R. Sheard, 1999. Manipulating meat quality and composition. Proc. Nutr. Soc., 58: 363-370.

Yoon, K.S., 2003. Effect of gamma irradiation on the texture and microstructure of chicken breast meat. Meat Sci., 63: 273-277.

Zouari, N., F. Elgharbi, N. Fakhfakh, A. Ben Bacha, Y. Gargouri and N. Miled, 2010. Effect of dietary vitamin E supplementation on lipid and color stability of chicken thigh meat. Afr. J. Biotechnol., 9(15): 2276-2283.