

REVIEW ARTICLE

PHYSICAL AND CHEMICAL FACTORS AFFECTING CHICKEN MEAT COLOR

A. Qamar¹, S.G. Mohyuddin¹, A. Hamza², K.A. Lartey¹, C.Q. Shi¹, F. Yang¹, Z. Lu¹, J. Yang¹, J.J. Chen^{1*}

¹Department of Veterinary Medicine, College of Agricultural Sciences, Guangdong Ocean University, Zhanjiang, Guangdong 524088 China

²Department of Information Technology, University of Education Lahore, Multan Campus, Pakistan

*Corresponding author's E.mail: jjchen777@aliyun.com

ABSTRACT: The expectation in term of meat quality characters has been increased due to consumer demand in the last few years. The quality of meat and meat products have a major concern and can never be compromised in any situation. Sensory qualities such as appearance, texture, juiciness, wateriness, firmness, tenderness, odor and flavor are the main factors, which influence the final meat purchasing decision of the consumer. It is well known that the darker color of thigh meat is due to the higher volume of myoglobin and haem pigments, as well as a higher pH when compared to breast meat. Killing older birds increases myoglobin amount in the meat and selection of breeds for higher breast meat production may be involved. Consuming a wheat-based diet tends to reduce the color of breast meat but has less effect on the thigh meat. After killing, biochemical variations, initiating the conversion of muscle to meat, regulate final meat quality. Heritability estimates for meat quality attributes in broilers are surprisingly high making genetic selection a best way for upgrading of broiler meat quality. However, the utilization of advanced new technologies, development of efficient and new processing methods will help to improve the chicken meat quality.

Keywords: Chicken, meat quality, consumer preference, genetics, feed.

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INTRODUCTION

Poultry meat production and consumption have been increased significantly in last few years. The increased production and consumption of meat is due to the higher demands of consumers to get a healthy diet, and meat is an essential component of a healthy diet (Marangoni *et al.*, 2015). Generally, customers like safe and good quality meat that has natural smell and taste. For good human health, chicken meat is rich in high quality protein and polyunsaturated fatty acids (Popova *et al.*, 2016). Balanced chicken meat consumption has favorable effects on human health. Some fast growing and indigenous breeds of chicken meet the requirement of poultry meat globally (Moussa *et al.*, 2019). In the United States (U. S.), poultry industry is the largest meat production industry. The average live weight in 1925 was 1.1 Kg for 112 days old broiler which was increased to 2.8 Kg in 2015 and achieved in 48 days (Kuttappan *et al.*, 2016). Total live weight produced during March 2019 was 5.20 billion pounds (NASS, 2019). Now consumers prefer the purchasing of cut-up parts especially breast meat rather than whole birds, which has increased to five points in the last ten years (Petracchi *et al.*, 2015), situation is same in 2019 (Rosa *et al.*, 2019). Generally, consumption of meat has been associated with many factors like age, sex and educational level. Sex is the main factor which influences the consumption of meat;

men consumed more meat than women (Pfeiler *et al.*, 2018; Stoll-Kleemann and Schmidt, 2017). Recent studies show that most young people like a vegetarian diet, at the same time young people consume more meat than older ones. Studies have shown that people with high education level tend to eat a vegetarian diet than meat consumption. According to these studies, personality is associated with meat consumption (Pfeiler and Egloff, 2017; Pfeiler *et al.*, 2018). The production and consumption of poultry meat are increasing throughout the world especially in Asian countries. Top seven meat consumption countries are shown in fig-1 (OECD/FAO, 2018). The second largest producer and consumer of chicken meat is China after the U.S. In the past 50 years, the consumers have eaten more chicken meat as compared to the beef meat in U.S. The increase in the consumption of chicken meat is due to certain factors, including consumer awareness, more convenient, lowest cost, easy preparation and health conditions like low level of cholesterol in chicken meat as compared to the beef or mutton meat (Michel *et al.*, 2011). This review has discussed how genetic, environmental and other factors affect the color of chicken meat.

Factors Affecting Meat Colour: The appearance, aroma, texture and taste are the primary criteria for the customers to purchase meat. Mainly the color of chicken meat influences the purchasing decisions of customers than

other quality factors. The color of chicken meat is measured in term of its lightness (L^*), redness (a^*) and yellowness (b^*) (Tomasevic and Rajkovic, 2015). There are many factors that change the color of chicken meat as described below:

Total haem content: Meat pigments are responsible for chicken meat color. These pigments are myoglobin (Mg), hemoglobin (Hb), cytochrome C and its derivatives. Myoglobin (Mg) is mainly responsible for chicken meat color (Faustman *et al.*, 2010). The structure of Mg is made up of the polypeptide chain, various histidine molecules and globin (Silverstein *et al.*, 2015; Mancini and Hunt, 2005). The Mb also contains a heme group. The protein performs its functions due to the globin chain which prevents the oxidation of heme iron and provides the water solubility to heme (Suman *et al.*, 2013). Different redox conditions of Mg are indication of fresh meat, these states are deoxy-myoglobin (DeoxyMb) that is purplish red in color, oxy-myoglobin (OxyMb) gives cherry red color, carboxy-myoglobin (COMb) gives red color, and met-myoglobin (MetMb) gives brown color to meat (Fig-2) (O'Sullivan, 2017). The preference for meat is decreased when oxymyoglobin (acceptable cherry red color) is converted into metmyoglobin (unacceptable brown color). In most of the research, it is concluded that the content of Mg is lower in breast muscle than thigh or leg muscle (Fleming *et al.*, 1991; Boulianne And King, 1998; Wideman, *et al.*, 2016). The meat of the leg or thigh is composed of red muscle fibers and breast meat composed of white fibers (Suman *et al.*, 2013). The Mg content is higher in red fibers. The thigh adductor and sartorius muscles have a higher amount of Mg and total heme than breast pectoralis muscle (Jiang *et al.*, 2014). Boulianne and King (1998) observed that excessively dark breast muscle meat exhibited greater total haem pigment and myoglobin contents (1.47 and 0.16 mg/g) as compared to the normal breast muscle meat (0.96 and 0.12 mg/g); hence it is concluded that there is a strong relationship between lightness values and heme percentage.

pH: The pH of the chicken meat also affects the color of meat. pH of meat is an essential factor, which together with color index should be used in measuring the quality of chicken meat. The higher value of pH results in darker meat color (Wideman *et al.*, 2016). The pH of the chicken meat is closely associated with water holding capacity (WHC). The meat with low pH value has low WHC which increases the cook and drip loss and also increases the shelf life of meat by reducing the meat tenderness (Popova, 2017). Struggling of the bird before slaughtering results in depleted muscle glycogen, and after slaughter, glycolysis process results in less accumulation of lactic acid in the muscles which increases the pH of meat (Mir *et al.*, 2017). Wattanachant *et al.* (2004) has shown that broiler thigh muscles had

6.62-pH value and breast muscles had 5.93-pH value. This study supports the theory that higher pH has darker chicken meat color. The denaturation of protein tend to the increased chances of autoxidation of Mb which results in significant color change due to low pH (Leygonie *et al.*, 2012).

Feed: For proper muscles growth and skeleton development, the feed of birds is crucial. The major contributors to the whole chicken meat are the minor and major breast muscles (Mcneill and Elswyk, 2016; Ahsan *et al.*, 2019). The birds that are fed on the wheat-based formulated feed had lighter color development than those birds fed on corn and milo-based feed. Corn-based formulated diet resulted in yellow color development. Similarly, milo based formulated diet resulted in red color development of chicken meat than corn and wheat-based formulated diet (Smith *et al.*, 2002). Pineda-Quiroga *et al.* (2017) has shown the effect of highly carotenoid (HC) maize on health, performance and color development in the broiler. They found that HC feed has no harmful effect on broiler health and develop similar skin color or pigmentation as developed by those birds that are fed on a commercial feed with feed color additives such as marigold flowers and red paprika extracts (Moreno *et al.*, 2017). However, commercial feed later significantly developed the higher yellowness due to the presence of xanthophyll. Research showed that the use of vitamin E and oil as a supplement in a chicken Feed affect the oxidation of protein and fat of meat during preservation. The usage of vitamin E enhanced the color 'L' value, but irradiation enhanced the 'a' value of broiler thigh meat (Zhang *et al.*, 2011). Ali *et al.* (2015) reported the effect of freezing and thawing process on protein denaturation, color changes and oxidation of protein and lipid in meat. They found that when the number of freezing and thawing cycle increased then it resulted in lipid and protein oxidation, protein denaturation and changed meat color.

Age, sex and breed of birds: The study had shown that the lightness value of the thigh and breast muscles decreases when the birds are slaughtered with increased age, but the sex of birds have no such type of effects. The darkness of the meat increases as the bird ages; this darkness may be due to a high level of myoglobin (Jaturasitha *et al.*, 2008; Wideman *et al.*, 2016). Abdullah *et al.* (2010) found relationship between the age of birds and meat color in broilers. They found that birds that are slaughtered at 42 days have higher lightness value (53.35) as compared to those slaughtered at 32 days (51.11). Young birds have a low level of subcutaneous fat, which leads to a bluish color (Brown, 2014). Age of bird has no particular effect on carcass quality and color development in chicken meat (Smith *et al.*, 2002). Abdullah *et al.* (2010) compared the Hubbard classic and Lohman strains of the broiler. They found that Lohman strain of broilers

was lighter in color than Hubbard strain. While, Brewer *et al.* (2012) reported that the strain and sex of the birds do not affect the color of chicken meat, these changes may be due to the difference in fillet size of the male and female birds. Generally, breast and thigh muscles color is not associated with sex, but the darkness of meat increases as the age of birds increases.

Rearing conditions and production practices: Rearing and production conditions also affect chicken growth and color development. At commercial level, the bird's activity is decreased due to high stocking density. Nevertheless, stocking density has no significant effect on sensory characters of meat. The study has shown that the low stocking density improved the flavor of cooked meat. In a carcass, the quantity of polyunsaturated fatty acids has been increased due to high ambient temperature (Mead, 2017; Hai-*tao et al.*, 2018). Almasia *et al.* (2015) compared the slow-growing strains of broiler grown under different conditions. The group of birds, which are grown outdoor, have darker color development in thigh muscles than those kept indoor. Similarly Kucukyilmaz *et al.* (2012) compared the slow and fast growing birds in the organic and conventional systems. Fast growing birds reared under the conventional system have reddish thigh and breast muscles, but slow growing birds have increased yellowness in meat.

Genetics: In the last few years, the breeder companies had developed new fast growing breeds of chicken through genetic selection which have improved performance in term of carcass quality and high yield of breast meat (Anadon, 2002; Mehaffey *et al.*, 2006; Boschiero *et al.*, 2018). Genetics may also affect the meat color of chicken. Berri *et al.* (2005) reported a significant difference by making a comparison between Ross and ISA chicken genotypes. They concluded that there was a significant difference in term of appearance and tenderness of breast muscles meat and the cooked flavor of thigh muscles meat. First time Le Bihan *et al.* (2001) reported the genetic effects on breast meat of chicken. These effects were obtained by using experimental broiler strains kept and slaughtered in a controlled environment without any effect on the meat quality. They found the highest value for chicken meat color in different meat characters such as drip loss, meat color, and pH (table-1). However, there was a correlation between the pH of muscles, meat color, and drip loss, because pH is a quality measuring factor of meat. Body weight and breast muscles were not strongly correlated with meat characters. Bianchi *et al.* (2006) experimented to measure the genetic effects on two different broiler genotypes (Ross 508 and Cobb 500). The birds were processed at different rearing conditions, antemortem conditions and with varying ages. Results showed that two commercial genotypes did not develop a significant color difference in breast muscles. The higher breast

muscles production is related to more lightness values of chicken meat (Santiago *et al.*, 2005), while Fengqi, (2012) showed no color difference with high breast production.

Freezing: The color of meat mainly depends upon the state of myoglobin present in the chicken meat. Frozen chicken meat negatively affects myoglobin stability. The frozen meat has higher met-myoglobin proportion and less reddish as compared to fresh meat (Bellés *et al.*, 2018). The content of myoglobin has been reduced due to freezing resulted in less red color meat (Seong *et al.*, 2017). Freezing may also favor the denaturation of myoglobin molecule that increases the chances of oxidation of chicken meat. The met-myoglobin rapidly accumulated in frozen meat than fresh meat, and an enzyme (metmyoglobin reductase) which convert the met-myoglobin into oxy-myoglobin is active in fresh meat (Jeong *et al.*, 2011).

Chilling: After the removal of viscera, the carcass must be chilled to avoid the growth of pathogenic bacteria. At commercial level, two methods are used for chilling of meat (Air chilling and wet chilling). In air chilling method, cold air is blown across or down the carcass for chilling purpose of the meat. In the wet chilling method, the carcass is dropped in a cold water one or two times. Agitation of cold water allows the meat to absorb water to a maximum limit designed by national legislation (Mead, 2017). Fleming *et al.* (1991) have shown the color and heme pigmentation level difference in air chilled and ice chilled breast and thigh meat. There was no significant difference in term of lightness, yellowness, and redness between methods. However, there was a significant difference in the heme content level of breast and thigh meat (Table-2). (Bowker *et al.*, 2014) also observed no difference in lightness, yellowness, and redness.

Future strategies to improve meat color and qualities: To improve the poultry meat quality, advancement in genetics through phenotypic progress in meat and from the development and selection of new breeds will be helpful. For example the development of such types of breeds of chicken which have low-fat contents and minimize the growth of pathogenic bacteria (Le Bihan and Berri, 2017). Meat color variation is predictable during packing and marketing, and therefore methods to persevere the color stability contribute mainly to profitability (Cullere *et al.*, 2018). Common approaches used to stabilize the meat color fall under two main categories: packaging and antioxidants. Packaging is entirely a post-harvest technique, while antioxidants can be both post- or pre-harvest technique. Modified Atmosphere (MAP) is the inclusion of meat products in gas-barrier constituents in which the gaseous environment has been different. Almost two-third of the fresh meat in the US is sold in MAP systems. In meat

production and supply chain, antioxidants can be used both post- or pre-harvest to decrease lipid oxidation which results in color deviation (Faustman *et al.*, 2010). Inaccessibility to adequate refrigeration also causes the hindrance for the marketing of many fresh foods including chicken meat. The utilization of modern chilling, freezing, packing and transportation system may reduce the chances to spoil the food by minimizing the growth of pathogenic bacteria (Beltra *et al.*, 2018). The welfare of birds and processing system should be under observation at all the time and should be suitable for

poultry production. Adequate production system and hygiene reduce the chances of cross-contamination. The utilization of advanced new technologies, development of efficient and new processing methods that fulfill the market and producer's requirement will be helpful in improving the chicken meat quality. There is need to modify the rearing and processing methods for chicken production. To determine the quality of meat, this highlights the need for future research to know the relationship between genetics and processing (Le Bihan and Berri, 2017).

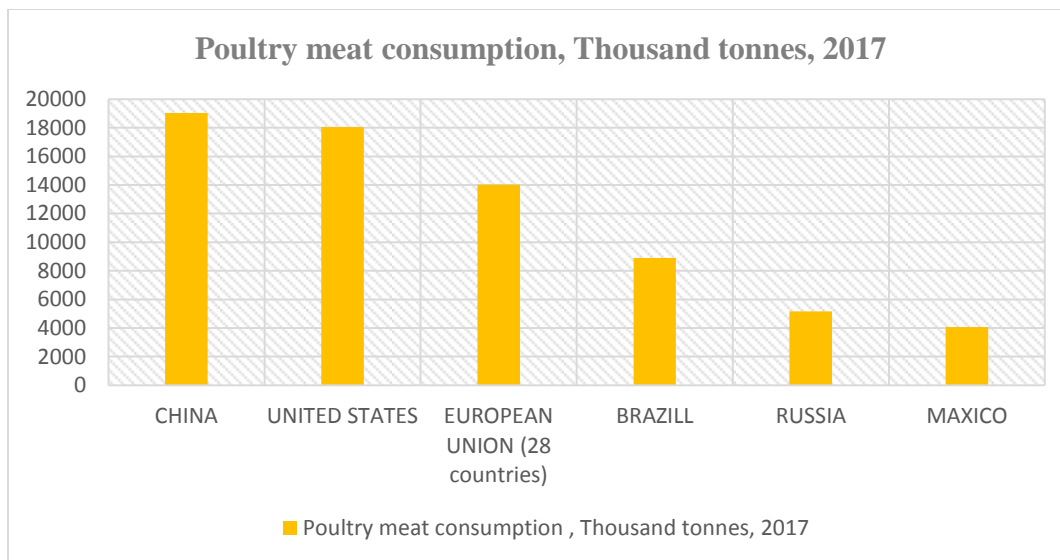


Figure-1: Top seven poultry meat consumption countries (Thousand tons, 2017) (OECD/FAO, 2018).

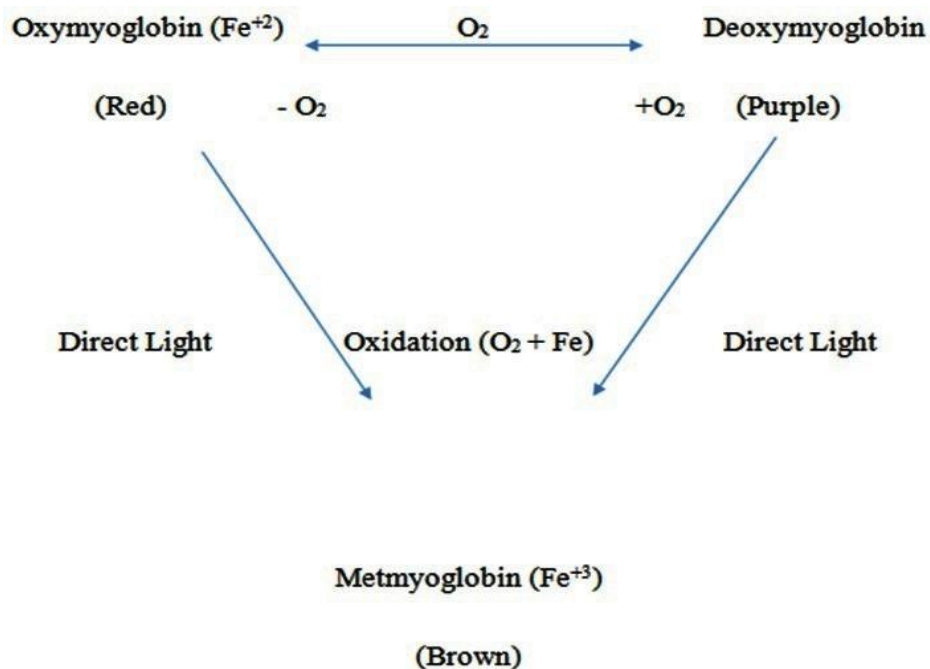


Figure-2: Conversion of oxymyoglobin into metmyoglobin (O'Sullivan, 2017).

Table-1: A measure of genetic characters for growth performance and breast meat quality in a broiler chicken
(Le Bihan *et al.*, 2001)

	pH15min	pHu	L*	a*	b*	DL	BW	BRY	AFP
pH15min	0.49	0.02	0.13	-0.23	0.05	-0.29	-0.06	0.12	-0.04
pHu		0.35	-0.91	0.14	-0.43	-0.83	0.07	0.13	-0.54
L*			0.50	-0.48	0.20	0.80	0.16	-0.07	0.50
a*				0.57	0.54	-0.25	-0.30	-0.29	-0.24
b*					0.55	0.16	-0.13	-0.39	-0.02
DL						0.39	-0.04	-0.16	0.29
BW							0.35	0.17	0.19
BRY								0.55	-0.17
AFP							0.6		

pH15min = pH after 15 min of post mortem; pHu = ultimate pH; L* = lightness; a* = redness; b* = yellowness; DL = drip-loss; BW = body weight; BRY = breast yield; AFP = abdominal fat percentage.

Table-2: Effect of chilling conditions on chicken broiler muscle.

Hunterlab value	Muscle	Ice slush	Air chilled
L value	Breast	41.18 ± .96 ^a	41.65 ± .84 ^a
	Thigh	36.99 ± 1.1 ^b	38.19 ± .89 ^b
aL value	Breast	2.24 ± .27 ^c	2.56 ± .23 ^c
	Thigh	5.67 ± .26 ^b	5.87 ± .20 ^b
bL value	Breast	5.20 ± .49 ^a	5.81 ± .51 ^a
	Thigh	5.10 ± .59 ^b	5.25 ± .49 ^b

^{a-c} Means with no common superscripts within a variable and chilling condition are significantly different at the 5% level. ¹Chilling conditions did not significantly affect Hunterlab values. ²A Hunterlab Tristimulus Colorimeter Model D25M-9 (Hunterlab Associates Laboratory, Inc., Reston, VA 22090) was used to obtain triplicate measurements of L, aL, and bL values where L = lightness, aL, = redness, and bL= yellowness. The colorimeter was standardized using a pink standard Number C2-6071 having an L value of 68.91, an aL value of 21.50, and a bL value of 10.75. ³Twenty observations per mean included pooled replicates (10 birds per replicate).

Conclusion: It was concluded that the quality of meat is dependent on many factors, any disturbance or faulty in these factors may affect the quality of meat. By considering these factors, we can design and produce more beneficial, healthy and economical meat for human consumption.

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