FACTORS AFFECTING THE QUALITY CHARACTERISTICS OF THAI INDIGENOUS CHICKEN MEAT

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Abstract

Thai indigenous chicken is one of the important chickens that are produced for consumption in Thailand. They make up almost 20 - 25% of total chicken production in recent year. The quality attributes of this chicken meat are concordant with consumer demands for its unique taste and texture and nutritious meat. Factors affecting its quality characteristics should be reviewed to gain knowledge for developing or promoting this chicken meat in the future. Different breeds or genotypes of the indigenous chicken can cause a difference in the color of the meat. Rearing systems, such as intensive and extensive farming, promote differences in meat texture. The indigenous chicken reared under the intensive system has more tender meat and yellowish in skin color. The appropriate age of the indigenous chicken for consumption or further processing products is suggested to be 16 - 18 weeks of age to ensure economical live weight and high meat quality. Aging condition, chemical composition and muscle protein properties are reflected in the quality of indigenous chicken meat. The indigenous chicken meat tends to have a longer time of rigor inset with lower ultimate pH compared to broiler meat resulting in lower water holding capacity. The high content of intramuscular collagen, but which is low in myofibrillar protein content, results in tough texture and high cooking loss in the meat during heating at 80 - 100°C. However, the indigenous chicken meat has high glutamic acid content but low fat and cholesterol contents. This, in concomitance with favorable fatty acid profiles, leads to the acceptably palatable meat that is desirable to consumers. The microstructure of muscle fiber and intramuscular connective tissue is the most important influence on the texture of indigenous chicken meat. Its muscle structure has very thick perimysium connective tissue and this is related to the high shear value of the meat.

Keywords: Thai indigenous chicken meat, poultry meat quality, quality factors

Introduction

In Thailand, the production of animals for consumption is economically beneficial and will tend to increase in the future. Chicken is produced mostly about 86% of total animal production in all parts of Thailand (Dept. of Livestock Development, 2008). Jittangsomboon (2000) reported that chicken production increased by 56.5% for domestic consumption and 43.5% for export. Thailand exported a total volume of 2,285.45 Tons of chicken, in chilled

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and frozen form, and 97.37% went to Vietnam (Dept. of Livestock Development, 2007). In all a total volume of 270,345 Tons of processed chicken meat was exported to Japan (54%), UK (25.59%), Netherlands (8.03%) and Germany (3.17%), as reported by the Department. of Livestock Development (2007). The export value of chicken was reported to increase from the year 1999 to 2000 (Katenil, 2000) and increased from 4,308 million baths in year 2002 to 35,462 millions baths in the year 2007 (Dept. of Livestock Development, 2007). The data clearly indicates that chicken is one of the most important commercial animals of the food industry of Thailand.

There are many chicken breeds in Thailand. Among those breeds, broiler, Thai or native indigenous chicken and laying hens are commercially produced for consumption. A total production of 283,076,272 heads of chicken consisted of 60.16% broilers, 22.38% native or Thai indigenous chickens, and 17.46% laying hens (Dept. of Livestock Development, 2008). Meat characteristics of the indigenous chicken are similar to that of spent hens but are much different from the broiler meat (Chuaynukool *et al*., 2007). The indigenous chicken generally has a slower growth rate than the commercial broiler when raised under the same commercial conditions. In addition, they have the traits of fighting cocks, including strong and firm muscles. This possibly contributes to the differences in the meat properties and quality of both types of chicken. A broiler aged 38-45 days has 1.2-2.0 kg live weight, while a Thai indigenous chicken aged 4 - 5 months will be of the same live weight. However, the indigenous chicken can be raised with lower production costs. Farmers generally simply raise them as free range using any organic feed or supplement with the concentrated pellet. Moreover, its meat has unique taste and texture and is regarded as a great delicacy, and has become very popular among Thai consumers. It is also an alternative for consumers preferring low fat and antibiotic-free white meat. This leads to a higher price, approximately two or three times higher than that of commercial broilers (Chotsangkad and Kongrattananun, 1999). A similar phenomenon is also seen in Hong Kong, Southern China and Japan (Ding *et al*., 1999). Leoytarakul and Pimkumhlai (1999) reported that the consumption of Thai indigenous chicken meat is an increasing trend due to consumer believes that its meat obtained from free drugs or hormones chicken production.

However, very recently there was an out break of virus influenza H5N1 leading to problems in the uncontrolled free range extensive farming system used for Thai indigenous chicken production. Therefore, the production and breeding of Thai indigenous chicken should be developed as an intensive closed farming system (Wattanachant and Wattanachant, 2007). “Kai baan Thai” is the name given by the Thailand Research Funding for Thai indigenous chickens which are crossbred and produced through an intensive farming system. Many researchers in Thailand have been focused on the development of indigenous chicken production and the quality of the carcasses (Panja, 1998; Chomchai *et al*., 1998; Chotsangkad and Kongrattananun, 1999; Leoytarakul and Pimkumhlai, 1999; Jaturasitha *et al*., 2002). However, the quality of indigenous chicken carcass in these research studies was evaluated by comparing only its proximate chemical compositions. The quality of the meat, in terms of textural characteristic, microstructure and the chemical composition of muscle protein is very important for comparing meat from different breeds (Chomchai *et al*., 1998). Main factors influence on the chemical composition, the properties and structure of the indigenous chicken muscle should be studied since all related to its meat quality. The information gained from this review should be beneficial for controlling the fundamental quality factors on further development in the production, breeding and processing of Thai indigenous chicken to improve the live weight, growth rate, chicken meat quality and safety.

Quality characteristics

Five main characteristics contribute to the overall eating quality of meat. These are taste, texture, juiciness, appearance and odor. Among these characteristics, texture is probably considered to be the most important attribute by the average consumer (Dransfield, 1994; Chrystall, 1994). Mechanical factors (tenderness) and juiciness (succulence) contribute to different meat textures. The tenderness of meat is the sum total of the mechanical strength of skeletal muscle tissue and its weakening during the post-mortem aging of meat. The former depends on species, breed, age, sex and individual skeletal muscle tissue of animals and fowls (Takahashi, 1996). Meat tenderness originates in structural and biochemical properties of skeletal muscle fibres, especially myofibrils and intermediate filaments, and of the intramuscular connective tissue, the endomysium and perimysium, which are composed of collagen fibrils and fibers. Attractive appearance to consumer of indigenous chicken meat is performed by its carcass conformation, skin or meat color which might be related to chicken genotypes, feeds, rearing system or even processing condition. There are many intrinsic and extrinsic factors including genotype or breed, age, rearing system, feeds, chemical composition, structure, and properties of muscle and processing condition which can influence on different quality characteristics of chicken meat. In this review, therefore, each affecting factor is discussed in multiple approaches to related quality attributes of the Thai indigenous chicken meat.

Genotype

Genotype (the breed and strain) of chickens plays a major role in carcass fatness and meat quality (Jaturasitha *et al.*, 2008). The quality of meat from different Thai indigenous chicken breeds, such as the common Southern Thai native, Naked-neck, Kai Dang, Black-boned and the Northern Thai native chicken, were studied (Od-Ton *et al.*, 2004; Wattanachant *et al.*, 2004a; Wattanachant *et al.*, 2004b; Adulyatham *et al.*, 2006; Wattanachant *et al.*, 2007; Jaturasitha *et al.*, 2008). The chemical composition and quality characteristics of Thai indigenous chicken muscles from different genotypes are shown in Table 1. Naked-neck chicken breast and thigh muscles had slightly higher fat content but were lower in shear value and a* and b* value compared to those of the Southern Thai native chicken. The difference in muscle color profile between both chicken breeds contributed to significantly lower sensory scores on color preference of Naked-neck chicken (Adulyatham *et al.*, 2006). The slightly darker meat of Black-boned chicken and the higher redness of Northern Thai native chicken muscle have been reported by Jaturasitha *et al* (2008). Among the Thai indigenous chicken breeds studied, collagen content in their muscles was similar except for those of the Black-bone and Northern Thai native chicken (Table 1). The difference in this collagen content could perhaps be attributed to the differences in the analytical method used by researchers. Thai indigenous chicken muscles had shear force value in ranges of 1.8 - 2.7 kg for breast muscle and 2.4 - 4.2 kg for thigh muscle which were higher than those of commercial broiler chicken muscles (Wattanachant *et al*., 2004a; Chuaynukool *et al*., 2007; Wattanachant and Wattanachant *et al*., 2007). The high shear value relating to high collagen content of Thai chicken meat results in lower sensory score on tenderness and juiciness of cooked meat compared to broiler (Adulyatham *et al*., 2006). Water holding capacity of breast and thigh muscle of Thai indigenous chicken was not different among genotypes which were in consistent with cooking loss quality (Table 1). There were no difference in sensory score evaluation on color, juiciness, flavor, and tenderness between cooked naked-neck and Thai indigenous chicken meat (Adulyatham *et al*., 2006). All data obtained show that different genotypes has more influence on typical color characteristic of raw Thai chicken meat when compared at the same age of chicken.

Rearing and Feeding Systems

Generally, backyard or village production systems (the extensive system) are preferred for producing Thai indigenous chicken by homesteads since the production costs are very low. The chickens are allowed to scavenge on their own for resources around the homestead during the day and this is supplemented with concentrated feeds in the evening when they come back to roost and sheltered at night. However, this system cannot certify the quality of the chicken, especially the chicken live weight, the carcass percentage, the quality of the meat, and meat safety. In intensive rearing systems the chicken were kept in houses and provided with concentrated pellet feeds as the main diet, and given other supplements such as rice bran or chopped herbaceous banana stalks. This system provided the higher carcass percentage (Wattanachant *et al*., 2002; Od-Ton *et al*., 2004). Wattanachant and Wattanachant (2007) found that the indigenous chicken reared under the intensive farming system had a higher percentage of breast muscle when the age of chicken was older than 14 weeks. Rearing systems (intensive and extensive) did not affect the proximate composition of the chicken muscle. However, rearing under the intensive system

Table 1. Chemical composition and some quality characteristics of different genotypes of Thai indigenous chicken muscles

Item	Chicken genotype				
	Black-bone[1]	Northern Thai[1]	Southern Thai[2]	Naked-neck[2]	Kai Dang[3,4]
Breast muscle					
Chemical Composition (%)					
Moisture	72.10	72.90	73.40	73.00	72.80
Protein	24.40	24.70	24.20	24.10	23.00
Fat	0.53	0.51	0.20	0.22	2.88
Collagen (mg/g)	28.30	26.20	7.15	8.50	7.27
Shear value	41.70 (N)	51.20 (N)	2.4 0 (kg)	1.80 (kg)	2.70 (kg)
Cooking loss (%)	22.08	18.99	20.78	20.28	24.04
Meat color					
L*	50.70	54.90	67.30	61.70	53.60
a*	1.66	1.27	4.22	1.04	-0.60
b*	10.50	13.60	8.80	3.20	9.00
Thigh muscle					
Chemical Composition (%)					
Moisture	74.10	75.70	74.80	74.20	80.80
Protein	21.70	20.40	21.40	20.70	17.40
Fat	2.81	2.94	0.48	0.56	1.14
Collagen (mg/g)	36.30	42.20	13.12	14.05	10.33
Shear value	36.10 (N)	44.30 (N)	3.20 (kg)	2.40 (kg)	4.20 (kg)
Cooking loss (%)	20.12	23.38	20.46	21.05	19.66
Meat color					
L*	45.90	51.90	61.40	57.10	48.50
a*	3.87	5.27	8.84	3.16	0.16
b*	3.40	7.80	8.80	5.10	5.30

Note: - backyard production system and 1.3 kg of carcass weight was noted for naked-neck chicken while intensive rearing system and 1.0-1.1 kg of carcass weight noted for the others. All types of chicken studied were mixed-sex and slaughter age at 16 weeks.
- breast muscle (*pectoralis major*), thigh muscle (*biceps femoris*)

Source: adapted from [1]Jaturasitha *et al*. (2008); [2]Wattanachant *et al*. (2004b); [3]Wattanachant and Wattanachant (2007); [4]Chuaynukool *et al*. (2007)

resulted in a lower shear value of the raw and cooked indigenous chicken muscles and higher L*, a*, and b* value for skin color of the indigenous chicken. Therefore, rearing chickens with full feeding supplements provided chickens with high percentages of breast muscle, which was more tender and of a better quality of muscle protein, than muscle obtained from the extensive system.

Age

Animal age has been known to affect chemical composition, properties and structure of muscle which could all contribute to the quality of meat (Lawrie, 1991). Changes in composition, structure, properties of muscle protein, and meat quality of Thai indigenous chicken during growth from 6 to 24 weeks have been studied by Wattanachant and Wattanachant (2007). During the growth of the indigenous chicken, moisture content in muscle decreased from 77.8 to 71.6%, whereas protein and fat content increased from 21.5 to 24.0% and 1.35 to 3.9%, respectively. Total collagen was unchanged with the age of chicken while soluble collagen slightly decreased and this was not correlated to the shear value of chicken muscles (Nakamura *et al*., 1975; Wattanachant and Wattanachant, 2007). The tenderness of chicken meat decreased during muscle growth (Nakamura *et al*., 1975; Wattanachant and Wattanachant, 2007) probably because of the structural changes of collagen (Nishimura *et al*., 1996; Fang *et al*., 1999; Nakamura *et al*., 2004). The breast muscle skin color L*, a* and b* increased while b* value of muscle decreased with increasing age. Wattanachant and Wattanachant, 2007 stated that the appropriate age for indigenous chickens to possess economical live weight and high meat quality was in the range of 16 - 18 weeks of age. However, Thai indigenous chicken shows an appropriate age for consumption between 16 - 20 weeks, with 1.2 - 1.5 kg live weight in commercial terms.

Meat pH

Meat pH has been shown to be primarily related to the biochemical state of the muscle at time of slaughter and following the development of rigor mortis. This affects both the light reflectance properties of the meat as well as the chemical reactions of the myoglobin (Fletcher, 1999a). Muscle pH and meat color are highly correlated. In a survey of five commercial broiler processing plants, breast meat colors were found to range with lightness values (L*) from 43.1 to 48.8 with a strong negative correlation with muscle pH (Fletcher, 1995). As mentioned by Fletcher (1999a,b), higher muscle pH is associated with darker meat whereas lower muscle pH values are associated with lighter meat. In the extremes, high pH meat is often characterized as being dark, firm and dry (DFD) and the lighter meat as being pale, soft and exudative (PSE). The effect of pH on meat color is complex. One effect, as noted earlier, is that many of the haem-associated reactions are pH dependent. In addition, muscle pH affects the water binding nature of the proteins and therefore directly affects the physical structure of the meat and its light reflecting properties. In addition, pH affects enzymatic activity of the mitochondrial system thereby altering the oxygen availability for haem reactivity (Fletcher, 1999a). The muscle pH of Thai indigenous chicken was 5.80 – 5.93 for *pectoralis* muscle and 5.85 - 6.06 for *biceps femoris* muscle as reported by Wattanachant *et al*. (2004a) and Chuaynukool *et al.* (2007). The latter researcher found higher muscle pH for both muscles of Thai indigenous chicken which was related to the lower L* value of the muscles. Higher muscle pH is associated with darker meat than that of lower pH (Allen *et al*., 1998; Fletcher, 1999a, b). The low ultimate pH in Thai indigenous chicken muscles compared to broilers, especially in *biceps femoris* muscle, has been reported by Wattanachant *et al*. (2004a) and Chuaynukool *et al*. (2007).

Chemical Compositions

There are two major aspects of meat quality; “nutrition quality”, which is objective, and “eating quality”, as perceived by the consumer, which is highly subjective (Bender, 1992). Meat from poultry contains several important classes of nutrients and it is low in calories. The fat contains essential fatty acids; the proteins are good sources of essential amino acids (Mountney and Parkhurst, 1995; Van Heerden *et al*., 2002; Wattanachant *et al*., 2004a) and also excellent sources of water-soluble vitamins and minerals, such as iron and zinc (Van Heerdin *et al*., 2002; Boccia *et al*., 2005). Chicken contains about 16.44 - 23.31% protein, 0.37 - 7.20% fat, 0.19 - 6.52% ash, and 72.8 - 80.82% moisture content (Smith *et al*., 1993; Xiong *et al*., 1999; Abeni and Bergoglio, 2001; Al-Najdawi and Abdullah, 2002; Van Heerden *et al*., 2002; Wattanachant *et al*., 2004; Chuaynukool *et al*., 2007). The chemical composition of poultry meat has been shown to be related to species, breed, muscle type, sex, age, and method of processing of carcasses (Ngoka *et al*., 1982; Smith *et al*., 1993; Ding *et al*., 1999; Abeni and Bergoglio, 2001; Al-Najdawi and Abdullah, 2002; Van Heerden *et al*., 2002; Wattanachant *et al*., 2004; Boccia *et al*., 2005; Chuaynukool *et al*., 2007; Wattanachant and Wattanachant, 2007). Ding *et al*. (1999) showed significant differences in fat contents between broiler and local chickens. Wattanachant *et al*. (2002) found that Thai indigenous chicken muscle contained higher protein content but lower fat and ash content compared to broiler muscles. Different breeds and muscle types of Thai indigenous chicken also differ in chemical composition, as shown in Table 1.

Much of the value of a protein food is based on its amino acid content whereby the high nutritional value is related to a high presence of essential amino acids (Bender, 1992). Amino acids represent over 90% of the crude protein in the body of poultry (Hunton, 1995). The amino acid composition of *pectoralis* and *biceps femoris* muscles of Thai indigenous chickens compared to those in other poultry is presented in Table 2. Both muscles were very high in glutamic acid, arginine, leucine, aspartic acid and lysine. However, no significant differences in the presence of amino acid were

Table 2. Amino acids represented in the crude protein of Thai indigenous chicken meat compared to other poultry

Amino acid	Thai indigenous chicken (16 weeks)[1]		Broiler (38 days)[1]		Turkey (8 weeks)[2]	Goose (7 weeks)[3]
	biceps femoris	*pectoralis*	*biceps femoris*	*pectoralis*		
Histidine	2.75	2.85	2.49	2.90	2.00	2.20
Arginine	4.48	4.58	4.75	4.39	6.50	6.70
Threonine	2.87	3.12	2.96	3.02	3.90	4.20
Cystine	0.30	0.34	0.31	0.31	1.70	2.40
Tyrosine	2.85	3.10	2.90	3.03	2.80	3.60
Valine	2.04	2.20	2.08	2.16	5.00	4.60
Methionine	1.81	1.93	1.83	1.88	1.80	1.50
Lysine	3.15	3.35	3.16	3.41	5.60	5.50
Isoleucine	2.26	2.45	2.29	2.41	4.00	3.50
Leucine	4.11	4.39	4.19	4.29	7.00	7.00
Phenylalanine	2.89	3.07	2.94	3.01	3.50	4.00
Aspartic acid	3.34	3.68	3.48	3.64	6.60	8.50
Serine	2.36	2.46	2.44	2.38	4.70	3.60
Glutamic acid	6.63	6.54	6.33	6.35	12.60	12.30
Glycine	2.29	2.83	2.95	2.70	7.10	8.10
Alanine	2.60	2.80	2.66	2.80	6.00	6.10
Proline	2.05	1.98	2.03	1.93	5.70	5.60

Source: [1]Wattanachant *et al*. (2004a); [2]Fisher and Scougall (1982); [3]Nitsan *et al*. (1981)

observed between broiler and indigenous chicken muscles, with the exception of glutamic acid (Wattanachant *et al*., 2004a). Indigenous chicken muscles contained slightly higher glutamic acid content than broiler muscles ($P < 0.05$). Glutamic acid was found to have a detectable effect on the taste of chicken meat and this may contribute to the differences in flavor between the meats (Farmer, 1999). Glutamic acid is much higher in turkey and goose meat as compared to the meat of broiler and indigenous chicken.

Fat content and fatty acid composition of triacylglycerols in muscle are strongly related to meat quality, especially in terms of flavor, juiciness and tenderness (Miller, 1994). Hunton (1995) noted that high unsaturated fat intakes may be preferable for humans; however, unsaturated fatty acids are more prone to oxidation. Wattanachant *et al*. (2004a) reported that indigenous chicken muscle contained a higher percentage of saturated fatty acids ($P < 0.05$) and a lower percentage of polyunsaturated fatty acids ($P < 0.05$) as compared with broiler chicken muscle (Table 3). However, different results were found by Jaturasitha *et al*. (2008). The fatty acid profile of the indigenous chicken muscles was different in chicken breeds or genotypes. This was also possibly caused by the differences in the feed diets given to the breeds (Cherian *et al*., 2002). The different fatty acid composition of muscle probably affects the lipid stability and taste. However, there are some reports indicate that although the chicken received the same feed diet, differences in such meat components as unsaturated fatty acid were observed. These were probably due to differences in eating behavior between breeds. The indigenous chickens tend to scratch while eating and were observed to pick up feed particles more selectively than the broiler (Van Marle-Koster and Webb, 2000). However, Jaturasitha *et al*. (2008) stated that the indigenous chicken seemed superior in a health point of view because fat and cholesterol contents were low and fatty acid profile was favorable.

Muscle Proteins

The difference in muscle protein composition between chicken breeds and muscle types could be attributed to the difference in properties and texture of their meats (Wattanachant, 2004). It has been generally reported that in the protein composition of chicken breast muscle myofibrillar, sarcoplasmic, and stromal proteins comprised ~56.2, 42.3 and 1.5% of the total protein (Lan *et al*., 1995). In addition, Lawrie (1991) and Murphy *et al*. (1998) reported that the myofibrillar and sarcoplasmic proteins comprised ~60 and 30% of the total muscle protein respectively. Thai indigenous chicken muscles contained proteins varying in the range of 35 - 57%, 36 - 46%, 3 - 6%, and 8 - 15% for myofibrillar, sarcoplasmic, stromal, and alkali-soluble protein respectively, depending on chickens' age, muscle type and rearing system (Wattanachant *et al*., 2004a; Wattanachant and Wattanachant, 2007). Lower myofibrillar protein but higher stromal and alkali-soluble protein has been reported in the indigenous chicken when compared to fast growing broiler muscle (Wattanachant, 2004; Wattanachant and Wattanachant, 2007). The high content of stromal protein or collagen has been known to be related to the typical textural characteristics of indigenous chickens. The low myofibrillar protein and high stromal protein might result in low functional properties of the meat. This is in consistent with the high cooking loss observed in indigenous chicken muscle compared to broiler muscle (Wattanachant, 2004; Wattanachant and Wattanachant, 2007).

Myoglobin

The color of raw poultry meat is critical for consumer selection whereas the color of the cooked meat is critical for final evaluation (Fletcher, 1999a). The major contributing factors to poultry meat color are myoglobin content, the chemical state and reactions of the myoglobin, and meat pH. Myoglobin content has been shown to be primarily related to species, muscle type and age of the animal (Miller, 1994; Fletcher, 1999a; Young and West, 2001). The concentration of myoglobin differs from breed to breed as shown in Table 4. Within an animal, different muscles often have different concentrations of myoglobin, each generally reflecting their role in

Table 3. Fatty acid composition (% of total fatty acids) of chicken muscles from different breeds Thai indigenous chicken and other imported breeds

Fatty acid	Broiler[1]	Bresse[2]	Rhode Island Red[2]	Thai indigenous chicken		
				Southern native[1]	*Northern native*[2]	*Black-boned*[2]
Breast muscle						
C8:0	0.21			0.74		
C10:0	0.00			0.16		
C12:0	0.36	0.27	0.53	1.85	0.57	0.32
C14:0	0.87	0.93	0.61	2.31	0.72	1.20
C16:0	31.82	28.22	25.18	33.01	27.00	24.50
C17:0	0.21			0.33		
C18:0	14.56	8.24	8.58	22.72	8.05	8.75
C20:0	0.23			0.38		
C21:0		0.13	0.30		0.35	0.16
C22:0	0.31			0.57		
C23:0		0.55	0.57		0.54	0.35
C24:0	0.17	0.32	0.90	0.56	1.00	0.13
C16:1	3.33	4.27	2.97	1.24	3.46	2.65
C18:1	37.76	24.10	24.35	31.25	23.82	24.22
C20:1	0.74	0.33	0.30	0.41	0.18	0.44
C24:1	0.00			0.20		
C18:2 n-6	7.63	27.04	27.58	3.36	26.38	31.33
C18:3 n-3	0.16	0.61	0.46	0.00	0.52	0.68
C20:2 n-6	0.32	0.09	0.11	0.00	0.03	0.26
C20:3 n-3 n-6	0.16			0.00		
C20:4 n-6 n-3	0.45	2.25	4.03	0.27	3.72	2.36
C20:5 n-3	0.34			0.16		
C22:6 n-3	0.37	1.04	1.90	0.47	2.03	1.19
Total SFA	**48.76**	**38.65**	**36.68**	**62.64**	**38.23**	**35.41**
Total MUFA	**41.82**	**30.33**	**29.25**	**33.09**	**29.08**	**28.78**
Total PUFA	**9.42**	**31.02**	**34.08**	**4.26**	**32.69**	**35.81**
Thigh muscle						
C8:0	0.18			0.21		
C10:0	0.00			0.11		
C12:0	0.37	0.53	0.28	2.74	0.63	0.33
C14:0	0.95	0.71	0.77	3.06	0.75	0.81
C16:0	32.65	26.61	26.00	32.04	27.46	25.82
C17:0	0.29			0.32		
C18:0	14.97	8.43	8.71	25.61	9.82	7.61
C20:0	0.21			0.42		
C21:0		0.21	0.16		0.35	0.13
C22:0	0.26			0.63		
C23:0		0.47	0.35		0.57	0.34
C24:0	0.13	0.59	0.62	0.42	0.90	0.41
C16:1	3.44	3.11	2.96	1.47	2.59	3.78
C18:1	35.13	24.71	25.43	26.35	21.17	25.11
C20:1	0.68	0.28	0.33	0.74	0.08	0.31
C24:1	0.00			0.21		
C18:2 n-6	8.86	26.11	28.21	4.74	24.45	29.17
C18:3 n-3	0.13	0.51	0.68	0.00	0.68	0.58
C20:2 n-6	0.27	0.05	0.04	0.00	0.05	0.06
C20:3 n-3 n-6	0.14			0.00		
C20:4 n-6 n-3	0.56	3.95	2.75	0.21	5.92	2.58
C20:5 n-3	0.40			0.21		
C22:6 n-3	0.38	2.00	1.17	0.53	2.91	1.42
Total SFA	**50.01**	**37.55**	**36.88**	**65.55**	**40.48**	**35.45**
Total MUFA	**39.25**	**29.83**	**30.27**	**28.77**	**25.52**	**30.75**
Total PUFA	**10.74**	**32.62**	**32.05**	**5.69**	**34.01**	**33.80**

SFA = saturated fatty acids; MUFA = monounsaturated fatty acids; PUFA = polyunsaturated fatty acids. Breast muscle (*pectoralis major*), thigh muscle (*biceps femoris*)

Source: [1]Wattanachant *et al*. (2004a); [2]Jaturasitha *et al*. (2008)

the animal. Muscles involved in sustained repetitive action, like breathing, contain higher concentrations of myoglobin than muscles used less often (Young and West, 2001). As shown in Table 4, the *pectoralis* muscle of chicken, used for power take-offs, is paler than leg muscles. The relationship of animal species, muscle type and animal age on meat myoglobin content and visual color was indicated by Miller (1994). White meat from 8-week-old poultry had the lowest myoglobin content (0.01 mg/g meat) compared to the white meat of 26-week-old poultry (0.1 mg/g meat), white meat of young turkey (0.12 mg/g), dark meat of 8-week poultry (0.4 mg/g), dark meat of 26-week poultry (1.5 mg/g), dark meat of 24-week turkey (1.5 mg/g), respectively. From the literature myoglobin content was seen to be significantly higher in broiler *pectoralis* muscle than that of indigenous muscle (Table 4). However, there was no significant difference in myoglobin content of *biceps femoris* muscle between both breeds. Non-significance in color L*, a*, and b* value between broiler and Thai indigenous chicken muscle was also reported by Wattanachant *et al*. (2004a). This report was not in agreement with Miller (1994), who stated that the content of myoglobin increased with the increasing age of poultry meat, and Ledward and Shorthose (1971) who stated that the differences in growth rate affected the different myoglobin content in lamb. The *biceps femoris* muscle of indigenous chicken contained higher myoglobin content than that of *pectoralis* muscle, whereas no significant differences were found between both muscle types of broiler chicken. The higher myglobin content in *biceps femoris muscle* of the indigenous chicken contributed to higher a* value and lower L* value compared to that of the lower myoglobin content in *pectoralis* muscle.

Microstructure of Muscle

The structure of muscles is largely defined by sheaths of connective tissue. There are three levels of organization: individual muscle fibers are surrounded by a fine network of the connective tissue, the endomysium; bundles of fibers are surrounded by the perimysium; and the whole muscle is contained within the epimysium (Lluch *et al*., 2001). The diameters of muscle fibers differ from one muscle to another and between species, breeds and sexes (Lawrie, 1991). The average diameters of chicken white fibers has been reported to be 68.2 µm (Kiessling, 1977), 38 to 46 µm (Smith and Flethcher, 1988), and 32.6 µm (Smith *et al*., 1993) for other breeds.

Table 4. Concentration of myoglobin (mg/g) within muscles of chicken

Muscle	Myoglobin concentration (mg/g)
Other chicken breed[1]	
Pectoralis	~0.10
Vastus lateralis	2.80
Vastus intermedius	5.00
Biceps femoris	0.70
Rectus femoris	2.50
Gizzard	19.00
Broiler (aged 36 days)[2]	
Pectoralis	5.60
Biceps femoris	4.70
Thai indigenous chicken (aged 16 weeks)[2]	
Pectoralis	3.40
Biceps femoris	4.70

Source: [1]Nishida and Nishida (1985); [2]Wattanachant *et al*. (2004a)

These are bigger than that of Thai indigenous chicken which are reported to be 26.6 - 28.9 µm (Wattanachant *et al*., 2005a) and 16.1 - 18.7 µm (Chuaynukool *et al*., 2007). These differences in muscle fiber diameter were possibly due to the differences in age, rate of rigor onset and degree of sarcomere shortening (Smith and Fletcher, 1988). Lawrie (1991) stated that the size of the muscle fiber bundles determines the texture of the muscle. However, there is an indirect correlation between muscle fiber diameter and tenderness. Ozawa *et al*. (2000) found that the white muscle fiber content (larger diameter and narrow Z-lines) was negatively correlated with shear value while red muscle fiber content (wide z-lines) was positively correlated to this value. The average of sarcomere length of post-rigor raw muscle from Thai indigenous, spent hen, and broiler breeds were significantly different in the range of 1.55 - 1.62 µm for *pectoralis* muscle and 1.53 - 1.64 µm for *biceps femoris* muscle as reported by Wattanachant *et al*. (2005a) and chuaynukool *et al*. (2007). Sarcomere length is used as a measure of muscle contraction and is highly correlated with tenderness of pre-rigor and rigor meat (Lyon and Buhr, 1999). However, in post-rigor meat, wide ranges of sarcomere length among bovine muscles are observed but this has a weak correlation with the shear value (Torrescano *et al*., 2003).

The relative proportion of connective tissue and muscle fibers vary between muscles and, in part, accounts for the relative toughness of meat (Lawrie, 1991). The specific influence of intramuscular connective tissue depends on their thickness, which is the amount of collagen present, as well as the density and type of cross linkages between collagen fibrils (Xiong *et al*., 1999; Wattanachant *et al*., 2004a, 2005a). The amount of the perimysium around each bundle is important. A high correlation between the thickness of perimysium and shear values of chicken muscle ($r^2 = 0.95$) was reported by Liu *et al*. (1996). The thicknesses of perimysium of Thai indigenous and broiler chicken *pectoralis* and *biceps femoris* muscles and shear values are shown in Table 5. As reported by Wattanachant *et al*. (2005a), the perimysium of indigenous chicken muscles were thicker than those of broiler muscles ($P < 0.05$). The perimysium of *pectoralis* muscle was thinner than those of *biceps femoris* muscle ($P < 0.05$). Thick perimysium in indigenous chicken muscles was coincidental with higher collagen contents and shear values of this breed muscle. The differences in the thickness of perimysium and the collagen content between the two breeds may be contributed to differences in the age of the birds (Dawson *et al*., 1991). However, with increasing animal maturity, the total collagen content of muscle does not increase (Dransfield, 1994) and does not correlate significantly with the tenderness of meat (Nakamura *et al*., 1975). Therefore, the difference between the breeds might be primarily due to genetic factors influencing the perimysium thickness and collagen content,

Table 5. Thickness of perimysium and shear value of chicken muscles from broiler and Thai indigenous chickens

Breed	Muscle	Thickness[1] of perimysium (µm)	Shear value[2] (kg)	
			raw	cooked
Broiler	*biceps femoris m.*	9.93 ± 2.28 [c]	2.89 ± 0.52 [c]	0.77 ± 0.18 [a]
	pectoralis m.	3.87 ± 1.32 [a]	1.20 ± 0.30 [a]	0.78 ± 0.23 [a]
Thai indigenous	*biceps femoris m.*	14.20 ± 3.45 [d]	5.20 ± 0.81 [d]	4.67 ± 1.09 [bc]
	pectoralis m.	7.10 ± 2.56 [b]	1.78 ± 1.08 [b]	4.09 ± 1.61 [b]

Data are presented as mean ± standard deviation. [1]n = 40; [2]n = 16
[a-d]Means with differing superscripts in the same column are significantly different ($P < 0.05$).
Source: adapted from [1]Wattanachant *et al*. (2005a); [2]Wattanachant *et al*. (2004a)

resulting in the differences in textural properties.

Post-mortem Aging

Tenderness of meat is the sum total of the mechanical strength of skeletal muscle tissue and its weakening during post-mortem aging of meat. During refrigerated postmortem storage, improvement in meat tenderness, commonly called meat aging, occurs. The major factor responsible for postmortem improvement in meat tenderness is degradation of muscle proteins. To obtain meat of high quality, post-mortem aging of meat at around 4°C for a certain period is required. Aging periods are usually more than 0.5 - 1 days for chicken. Both tenderness and flavor are improved during this aging time (Takahashi, 1996). Post-mortem changes of Thai indigenous chicken had been studied by Wattanachant (2004). The indigenous chicken meat had a slower pH decline and contained higher lactic acid content, compared to broiler meat, leading to the lower ultimate pH. Broiler meat had a higher degree of proteolysis than indigenous chicken meat as evidenced by a significant increase in TCA-soluble peptides especially early post-mortem. However, no change in soluble collagen in meat of both breeds during the aging period has been reported. Improvement of tenderness of meat by proteolysis required at least 4 h and 6 h post-mortem aging at 4°C for broiler and Thai indigenous chicken carcasses, respectively, have been suggested by Wattanachant (2004).

Processing

Chicken meat can be processed in many forms and is mainly available fresh, chilled or frozen, broiled, roasted, canned, and sometimes in combination with other ingredients and foods. The quality of chicken meat and chicken meat products can be influenced by the way it is processed and the temperature used. The temperature at which poultry is held during chilled storage determines to large extent its shelf-life (Mountney and Parkhurst, 1995). Chilled poultry stored at 2 - 4°C have a shelf-life of one or two days at maximum before dispatch to retail outlets and may be kept a day or so longer if stored at -1°C (Silverside amd Jones, 1992). Poultry kept in frozen storage at -20°C may be kept for up to 6 months (Mountney and Parkhurst, 1995). During refrigeration or frozen storage, raw or cooked poultry undergoes several changes such as microbial growth, chemical and physical changes that can affect their quality attributes that may result in reduced consumer acceptance (Bustabad, 1999; Kim and Marshall, 1999; Woods and Church, 1999).

Lipid oxidation is one of the most important degradation processes during meat refrigeration. The breast meat of Thai indigenous chicken has been reported to have an increase in TBARS value for 23% within 6 days of chilled storage and 73% at 9 days of chilled storage (Wongwiwat *et al*., 2007). Marinade technique could extent the shelf-life of indigenous chicken meat. Wongwiwat *et al*. (2007) reported that the mixed spices in lemon glass marinade cuisine could retard the lipid oxidation, drip loss and microbial growth in ready-to-cook Thai indigenous chicken meat during storage. This process could preserve the chilled indigenous chicken meat product for 12 days.

Thermal processing of poultry results in chemical and physical changes that will strongly influence chemical composition, cooking loss, yield and other important quality factors such as texture, juiciness, color, and flavor, which are associated with palatability and consumer acceptance of the final product (Califano *et al*., 1997; Murphy and Marks, 2000; Wattanachant *et al*., 2005b). Wattanachant *et al*. (2005b) studied the effect of heating temperature on changes in textural properties of Thai indigenous chicken and broiler meat. They found that shear value of indigenous chicken meat slightly increased when heated from 50 to 70°C and dramatically increased at 80°C. No changes in shear value of the indigenous chicken meat were observed when heated at 90 - 100°C. The increase in shear value with heating up to 80°C might be due to the combination effect of the denaturation of myofibrillar proteins, the shrinkage of intramuscular collagen, as well as the shrinkage and dehydration of the actomyosin (Bailey and Light, 1989). Palka and Daun (1999) pointed out that cooking loss and sarcomere length seemed to be a good indicator of changes in meat during cooking. Wattanachant *et al*. (2005b) observed that the greatest shrinkage of the sarcomere in muscle heated to end-point temperature of 70 - 100°C for broiler and 80 - 100°C for indigenous chicken related to the greatest increases in cooking losses of both chicken meats at the same range of heating temperature.

With increasing heating temperature, meat tended to be lighter and also turned to a brown-grey hue. The lightening is due to an increased reflection of light arising from light scattering by denatured proteins (Young and West, 2001). The loss of chroma and change in hue result from the changes in myoglobin. Myoglobin is one of the more heat-stable of the sarcoplasmic proteins, which is almost completely denatured between 80 - 85°C (Lawrie, 1991). For this reason, Wattanachant *et al*. (2005b) reported that the muscle color of Thai indigenous chicken, lightness (L*) and yellowness (b*), was found to increase significantly with increasing temperature in the range of 50 - 70°C and no changes were observed when heated to higher temperatures (80 - 100°C). However, the redness (a*) of indigenous chicken muscle increased significantly when the muscle was heated to endpoint temperature of 70°C and decreased when heated to higher temperatures.

Conclusions

Many factors such as breeds or genotypes, rearing systems, feed, age, muscle pH, chemical compositions, microstructure of muscle, post-mortem aging and processing methods can influence on the quality of indigenous chicken meat. Breeds or genotypes show more impact on color and appearance of Thai indigenous chicken meat but less influence on chemical compositions when determined comparatively at the same age of slaughter. The quality of the indigenous chicken meat might be related to its composition especially the muscle proteins, intramuscular collagen and intramuscular fat content which are strongly affected by the breed, rearing system and age of the chicken. Amino acid and fatty acid composition have been known to have an effect on chicken meat taste and flavor that can be influenced by genotypes, rearing systems and feeds. Providing different feeds to indigenous chickens also has effects on the color of chicken meat especially skin color. Meat pH is affected by breeds, muscle types and post-mortem aging of the indigenous chicken and is very important in determining the textural properties and color of the indigenous chicken meat. The information on proteolytic enzymes relating to post-mortem change during aging of the indigenous chicken muscle is still limited. Microstructure of muscle especially for intramuscular connective tissue highly influence on the texture of the indigenous chicken meat which is related to the breed and age of the chicken. The firm texture of the indigenous chicken meat after cooking is a dominant quality that influences consumer acceptance. This textural characteristic of the indigenous chicken meat can result in resistance to the more severe processes. However, high cooking loss during heating process of this chicken meat may result in a lower yield of the chicken products after processing as compared to that of broiler meat. Therefore, the development of breeds to improve muscle protein quality of this chicken meat needs to be studied.

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