# CHAPTER 1

# INTRODUCTION

At present, there is a dramatic increase in consumption of poultry especially the chicken spreads economically. Thailand exports chicken in form of frozen and processed chicken meat tend to increase from 1999-2001 but decrease from year 2001-2004 (Livestock development, 2003). This is due to the spreading of Avian influenza in year 2003. In currently, Thailand has a major problem to export chicken in form frozen chicken meat due to awareness of Avian Influenza in poultry farms. Thermal processing with high temperature is one of the most effective inactivation destruction of H5N1 virus at temperature 70°C that would be enhance confidence of such product for consumers. Therefore the export of chicken meat in form of processed meat trends to be increased 13.2% in volume from year 2003 to 2006 (Livestock development, 2007).

There are many chicken breeds in Thailand. Among those breeds, broiler and Thai indigenous chicken are commercially produced for meat consumption in Thailand. While spent hen is mostly underutilized and used in low priced mince product at the end of egg laying cycle. These birds become available for use in further processed product (Nowsad *et al*., 2000). However, meat obtained from these birds has poor functional properties (Singh *et al*., 2001). The indigenous chicken muscles, both *pectoralis major* and *biceps femoris* muscles, posses firmer textures, particularly after cooking than those of the broilers are reported (Wattanachant *et al*., 2004). Therefore, meat obtained from different chicken breeds, ages and muscle types results difference in their properties which need to be processed for specific products.

Tom Yum soup has been regarded as a great delicacy and becomes very popular among Thai and foreigner consumers. However, the acid condition (pH 2.8-3.0) of Tom Yum soup may cause deterioration in texture and color of meat resulting in short shelf-life of product. The tough chicken meat with high collagen content and low amount of heat soluble collagen may be suitable for this product condition. Although, it is a good protein source, spent hen have minimal economic values in. The spent hen meat is very tough in comparison to those of broilers and roaster. Due to its higher collagen content, and its thus not well accepted by the consumer. Improvement in the textural and yield characteristic of aseptically processed chicken has been reported (Dawson *et al*., 1991). Retort pouches of low-acid solid foods appear to have attained some commercial acceptance and recognition of superior quality and more convenient packaging, the expectation is that other heat sterilized foods will appear in pouches, creating a new segment within the can foods category (Brody, 2003). Also, retort able pouch products can be alternative for consumer. The chicken meat should be developed to ready to eat value-added product with thermal. The information gained from this research will be beneficial for the improvement and development of chicken meat and may be helped to the exporter.

# Literature Reviews

## 1. Chicken

### 1.1 Thai indigenous chickens (Kaidang)

Thai indigenous chicken, Kaidang is one of slow growth rate chicken breed. There are consumable live weight at 1.2-2.0 kg when its age 4-5 months. However, the indigenous chicken can be raised with the low production cost if compared to broiler, commercial fast growth rate chicken breeds. Farmers generally simply raise them in free range with any organic feed or supplement with the concentrate pellet. Moreover, its meat has unique taste and texture and has been regarded as a great delicacy and becomes very popular among consumers. It is also an alternative for consumers preferring low fat and antibiotic-free meat. This lead to a higher price, approximately two or three times higher than that of commercial broiler (Chotsangkad and Kongrattananun, 1999).

### 1.2 Broiler

Standard intensively farmed broiler chickens are reared until slaughter weight of 1.8-3.0 kg within just 6 weeks of being hatch. As broilers are bred to grow as fast as possible this has lead to them becoming more inactive. They are rapid growth and high yields. Various ages 32 to 62 days and weights 3-8 lbs of birds are now being processed within the industry to fit different food markets (e.g., fast food, tray pack, further processed, etc.) (Mehaffey *et al.,* 2006). According to Stewart and Amerine (1982), broilers constitute the largest proportion of the commercially available chickens. The quality of broilers as raw material for manufacture of processed meat products has been improved through breeding, feeding and management.

### 1.3 Spent hen

Hens can supply eggs for two to three years before being regarded as spent hen, but a depression of egg prices shortens this time (Li, 2006). An excessive of spent hens has become a problem. Spent hen meat is mostly potential underutilized raw material ordinary and used in low priced. At the end of egg laying cycle (usually at 85 to 100 weeks) these birds become available for use in further processed. Age makes its muscle objectionable toughness of meat because of high amounts of heat-stable collagen (Nowsad *et al*., 2000). This is due to an increase in collagen cross linking in older animals contributes to meat toughness (Goll *et al*., 1963; Bailey, 1972; Nakamura *et al*., 1975; Swatland, 1984). This toughness has precluded its use in whole meat foods and has reduced its market value (Sams, 1990; Naveena and Mendiratta, 2001.). Spent hen meat posses serious problems with regard to both processing and utilization (Singh *et al*., 2000). The direct use of meat from spent hens causes problems because collagen content increase with age (Wu *et al*., 1996). Spent hens have been used in canned products such as soup, sauces, stews and gravies or as stewing hens (Voller *et al*., 1996). Ajuyah *et al*. (1992) found spent hens to be high in n-3 fatty acids and suggested that they would be useful in the development of health-oriented further-processed poultry products.

## 2. Chemical composition of chicken meat

Chicken is one of the most economically important poultry in Thailand. Chicken meat has protein by 19% and fat 5% that its is a leading source of protein but lower fat than pork and beef (Heerden *et al*., 2002). There are many studies show that breed, gender, age and feeding regime influence animal growth rate, meat yield and composition (Eilert and Mandigo, 1993). Chemical composition of chicken meat has been showed to be affected by age and breed as elucidated in Table1 (Wattanachant *et al*., 2004; Lee *et al*., 2003).

**Table 1** Chemical composition of meat from Thai indigenous chicken, broiler and spent hen

| Breed | Moisture | Protein | Fat | Ash |
|---|---|---|---|---|
| [1]Thai indigenous | 74.88 ± 0.61 | 22.05 ± 0.62 | 0.37 ± 0.14 | 1.03 ± 0.04 |
| [1]Broiler | 74.87 ± 0.46 | 20.59 ± 0.26 | 0.68 ± 0.06 | 1.10 ± 0.01 |
| [2]Spent hen | 67.46 ± 3.13 | 24.36 ± 2.81 | 7.15 ± 0.09 | 1.04 ± 0.09 |

**Source**: [1]Adapted from Wattanachant *et al*. (2004)

[2]Adapted from Lee *et al*. (2003)

Wattanachant *et al.* (2004) studied on chemical composition, textural characteristics and microstructure of *pectoralis major* and *biceps femoris* muscles from Thai indigenous chicken and broiler of similar weight but difference age. Thai indigenous chicken muscles contained higher protein but lower fat than broiler muscles ($p$<0.001). For protein composition of chicken muscle from both breeds found that the indigenous chicken muscle had lower myofibrillar and sarcoplasmic protein fractions ($p$<0.05) but much higher stroma and alkalisoluble protein fractions ($p<0.05$) compared with that of broiler muscles. Indigenous chicken muscles contained larger total collagen but less soluble collagen than those of broiler muscles ($p<0.001$).

**3. Quality characteristics of muscle foods**

Quality is the most important criterion from the point of view of the consumer (Califano *et al.,* 1997). Christensen *et al*. (2000) reported that 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. As discussed previously, meat contains several important classes of nutrients such as a concentrated source of protein which is not only of high biological value but its amino acid complements, its is also a good source (Bailey and Light, 1989). Five main factors contributing to the overall eating quality of meat include taste, texture, juiciness, appearness and odour. For poultry, color, texture and flavour are the main factors contributing to the eating quality (Northcutt, 1997). Among these factors, texture is probably considered the most important attribute by the average consumer (Dransfield, 1994; Chrystall, 1994). The quality attributes that influence the acceptability of various meat, poultry and fishery products should be considered how they may differ. Quality characteristics of meat are influenced by various intrinsic and extrinsic factors, such as muscle structure and its chemical composition, antemortem stress, as well as postmortem handling and storage condition as concluded by Xiong *et al*. (1993).

**4. Factor affecting quality characteristics of muscle**

**4.1 Color**

Color of raw poultry meat is critical for consumer selection whereas 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 reaction of the myoglobin and meat pH. Fletcher *et al.* (2000) reported that the extremes in raw breast meat color and pH variation also affected cooked meat color and pH. Breast meat may appear darker due to high muscle pH (Allen *et al*., 1998). These findings were confirmed by Eilert and Mandigo (1993) who observed that ground chicken meat with high pH was darker, redder and yellower in color than meat with low pH. Cornforth (1994), also stated that meat with a high pH has a higher waterbinding capacity, hence making it appear darker. Wattanachant *et al.* (2004) reported that *biceps femoris* muscle had lower L* but higher a* values than *pectoralis major* muscle of Thai indigenous chicken and broiler that was related to difference in muscle pH and myoglobin content between the muscle types.

**4.2 Texture**

The most important quality attribute of chicken meat is texture (Smith and Fletcher, 1988; Dransfield, 1994; Chrystall, 1994). For intact meat, texture of muscle refers to the definition and fineness of muscle fibers and the amount and distribution of fat in the muscle. In this case meat texture is determined by the age of the animal, the type of muscle, gender and the growth condition (Xiong *et al*., 1999). Tenderness is a quality attribute uniquely important to meat texture. The role of tenderness in meat quality varies with species. Tenderness of meat may be simply defined as the ease of teeth to cut meat fibers during mastication. For intact or noncomminuted meat, tenderness or toughness is determined by two groups meat component the connective tissues and muscle fibers (Xiong *et al*., 1999). There are many factors consider to influence meat texture such as intramuscular fat (Miller, 1994; Fernandez *et al*., 1999), intramuscular connective tissue (Liu *et al*., 1996), muscle fiber types (Ozawa *et al*., 2000), myofibrillar structure (Palka and Daun, 1999) and post-mortem carcass aging temperature and time (Duun *et al*., 1993; Duun *et al*., 2000). From previous report, *pectoralis major* muscle (breast muscle) and *biceps femoris* muscle (thigh muscle) can be represented for tender and tough muscle as related to their shear values (Liu *et al*., 1996). Wattanachant *et al*. (2004) compared the shear force values of Thai indigenous chicken and broiler muscle. *Pectoralis major* and *biceps femoris* muscle of the indigenous chicken, either raw or cooked were higher compared to the broiler muscles ($p$<0.01). The amount, composition and arrangement of the intramuscular connective tissue directly affect the texture of meat. Collagen is the major component of the intramuscular connective tissue and plays a key role in determining meat toughness (Liu *et al*., 1994). Liu *et al.* (1996) indicated that the total amount of collagen and structures of the perimysium are the major factors determining toughness of chicken meat. Some literatures referred that between animals, the age-associated increase in collagen cross-linking or decreased collagen solubility significantly affects muscle tenderness (Nakamura *et al*., 1975; Miller, 1994). A number of factors such as age, sex and strain have been shown to affect meat tenderness. These factors have also been shown to affect muscle fiber type and diameter. Therefore older birds have been shown to yield tougher meat than younger birds (Ahn *et al*., 1993). Warriss (2000) stated that age was a more important influence on breast meat tenderness than sex or body weight. Sams (1990) found that meat from 72 weeks old laying hens was significantly tougher than meat from 10 weeks old broiler. Fiber diameter has been shown to be affected by body weight, age and sex (Northcutt *et al*., 1998). Thus, it is well established, texture is a major criterion in meat quality and is an important determination of meat preference. Tenderness of meat is the sum total of the mechanical strength of skeletal muscle tissue and its weaking during post-mortem aging of meat. The former depend on species, breed, age, sex and individual skeletal muscle tissue of animal and fowl.

Liu *et al*. (1996) found that collagen content and thickness perimysium connective tissue affected toughness of chicken muscle. The amount, composition and arrangement of intramuscular connective tissue directly affect the texture of meat (El, 1995; Liu *et al*., 1996; Foegeding and Lanier, 1996; Pearson and Young, 1989). Intramuscular connective tissue is an important constituent when the physical properties of meat are considered, although the amount of collagen and elastin in muscle is low (Palka, 1999).The collagen content and its property are important because it contributes significantly to toughness in muscle. The properties of collagen are dependent on its structure and composition with change as animal age. Collagen molecules of intramuscular connective tissue changes to a structure as the age of an animal and consequence to their thermal stability and tensile strength through the formation of cross-linkages (Foegeding and Lanier, 1996; Nakamura *et al*., 1975; Pearson and Young, 1989). As cross-linking of collagen increase it becomes less soluble but increase in heat resistant (Foegeding and Lanier, 1996; Rochidi *et al*., 2000). It correlates to toughness in muscle (Miller, 1994; Nakamura *et al*., 1975). The crosslinking extent can be measured by determination of the thermal solubility of collagen or by differential scanning calorimetry (Torrescano *et al*., 2003).

There is a large individual variation in meat quality both within and between animals of the same breed, age, strain and environment. These factors have also been shown to affect muscle fiber type and diameter. However, few studies have established a direct cause and effect relationship between muscle fiber type and diameter to subsequent meat tenderness. (Lawrie, 1991; Smith and Fletcher, 1988). Besides, Smith and Fletcher (1988) determined the influence of muscle and location within the muscle on fiber type and diameter of difference age.

Age is also important for fiber type. Shorthose and Harris (1990) reported that the relationship between fiber diameter and shear force became variable when adjusted for age, indicating age was more important than fiber diameter in meat tenderness. A positive relationship between muscle fiber diameter and meat toughness has been reported in red meat species (Lawrie, 1991). Wattanachant *et al.* (2004) reported the fiber diameter and perimysium thickness of Thai indigenous muscles were larger than those of broiler muscles ($p$<0.05) while the sarcomere length of both muscle types from both breeds were in range 1.56-1.64 µm. The differences in protein composition and collagen content, resulting in the differences in textural properties. Indigenous chicken muscle either raw or cooked were higher shear value compared to the broiler have been reported (Wattanachant *et al.*, 2004).

**5. Effect of pH on meat quality**

pH was clearly identified as a major factor influencing the water-holding capacity (WHC) of homogenized meat systems, a minimal effect occurring at the iso-electric point (IEP) of the major proteins in muscle (pH 5.0 to 5.5) and increasing markedly with changing pH on either side of the I.E.P. Penny *et al*. (1963) demonstrated a similar phenomenon with purified beef myofibrils over the pH range 4.5-7.5, which they attributed to changes in muscle fiber diameter. Offer and Trinick (1983) have since observed an increased swelling of individual myofibrils over the pH range 5.0-9.0 as part of a more extensive study showing the beneficial influence of salt and pyrophosphate solutions on myofibrillar swelling at the IEP. These observations not only substantiated the earlier work of Hamm (1960) and Penny *et al*. (1963) but prompted the first structural hypothesis of water-holding in meat based on the swelling or shrinkage of myofibrils caused by expansion or shrinkage of the myofilament lattices.

Miles and Lawrie (1970) were perhaps the first to identify a relationship between pH and meat tenderness using cooked rabbit muscle, tenderness increasing linearly with increasing pH over the range 5.5-7.1. More extensive studies on mutton (Bouton *et al*., 1981) and beef (Bouton *et al*., 1981) not only confirmed this pH effect on cooked meat tenderness, but also identified a linear increase in WHC over the same pH range. The pH of meat products is of a great importance because of its major influence on water holding capacity, tenderness, juiciness and on the interaction of the meat with different salts (Bendall, 1979; Rao *et al*., 1989). It also determines the stability of the meat with respect to autolytic and microbial degradation (Saunders, 1994). Changes in pH are caused by postmortem metabolism (Koohmaraie *et al*., 1992) and by the application of substances (acids) added to the meat during technological processes like marination (Gault, 1985). They can also be caused by the activity of microorganisms during fermentation (Twiddy *et al*., 1987). Acetic acid and to a lesser extent lactic acid are commonly used in meat marination to tenderize and flavour the meat and to cause the fibres to swell (Berge *et al*., 2001; Hamm, 1977). A large number of protons are required to reduce the pH of meat, due to its buffering capacity. Most of the added protons bind to various components of the meat and the remaining free protons are responsible for the pH value (Svensson and Tornberg, 1998). Several compounds in the meat act as proton acceptors or donors, which affects its buffering capacity. Their contribution to total buffering capacity varies according to the pH. The phosphate group, proteins and dipeptides (carnosine, anserine) act mainly at a pH close to neutrality while the acid amino acids and the lactates account for the buffering capacity observed at marination pH, in a pH range of 3-5 (Gault, 1991; Kyla-Puhju *et al*., 2004). Kivikari (1996) found a minimum buffering capacity of about pH 5.5-6.0 during acidification from initial pH, whatever the meat (ox, chicken, pig). The stronger buffering capacity on either side (neutral pH and pH around 4) might be related to the respective contributions of phosphates+proteins/dipeptides (neutral pH) and lactates (pH around 4). dipeptide content varies from meat to meat. Plowman and Close (1988) found that it was twice higher in chicken than in beef or pork. Kivikari (1996) showed that the buffering capacity of meats with different initial lactic acid contents was very similar above pH 5. There were only minor variations in buffering capacity for the same muscle of different animals, and the same was true of different muscles in the same animal. The chemical equilibrium occurring in the acidified meat must be investigated before a method of pH prediction can be developed. Few studies have been made in this field. Moreira *et al*. (1992) proposed an approach to predict pH change in acidified turnips. Their method takes account of acid diffusion and buffering capacity but a model has to be established for each acid used. In addition, the pH is given only after acid equilibrium with the immersion solution is reached. McCarthy *et al.* (1991) proposed a procedure to estimate the amounts of acid required to produce a desired pH in low acid foods. Foods are titrated with organic acids and samples are allowed to equilibrate to a representative pH after each addition of acid. The amount of acid required to acidify a given food to the desired pH is calculated from acid versus pH, i.e., titration curves. However, the results cannot be extrapolated to other operating conditions: other acids, concentrations, etc. Svensson and Tornberg (1998) proposed first titrating a minced meat with a strong acid. As the strong acid is completely dissociated, the number of protons bound to the various components of the meat at each pH value can be calculated by subtracting the free protons from the total amount of added acid. A calculation of the amount of acid to be added to reach a given pH can be proposed, as it is a matter of acidifying the same minced meat with a weak acid. Three assumptions need to be made: (i) that the amount of bound protons per mass unit of a given meat is related to the pH value of the medium (ii) that there is only one such relationship and (iii) that the value of the dissociation constant of the acid in question, known in aqueous medium, is preserved in this complex medium. These assumptions need to be checked to work out a reliable method. The predictions made by Svensson and Tornberg (1998) on beef, according to a dilution ratio of 1/6 were conclusive.

Tom Yum, mixed herbs acidified soup, a traditional Thai food has been regarded as a great delicacy and becomes very popular among Thai and foreigner consumers. In Japan and Thailand, researchers have discovered that some components found in galagal root, lemon grass and kaffir lime leaves, which are major ingredients of the soup, are effective in inhibiting tumors in the digestive tract (Siripongvutikorn *et al*., 2005). However, the acid condition (pH 2.8-3.0) of Tom Yum soup may cause deterioration in texture and colour of meat resulting in short shelf-life of product. The tough chicken meat with high collagen content and low amount of heat soluble collagen may be suitable for this product condition. The acid solution was found to have significant effects on pH, mass variation and water content in chicken meat (Deumier, 2004). Raw chicken was lightened in colour after immersing in lactic or citric solution. Deumier (2004) reported the decrease in colour a value of chicken meat as the processing time and acid concentration of the solution increased.

**6. Effect of thermal processing on physical and chemical properties of muscle**

Thermal processing has a large effect on meat toughness. Heating muscle food results in chemical and physical changes that will affect the texture, palatability and consumer acceptance of final product. Thermal processing in meat and poultry strongly influences texture, protein changes, cooking yield and other important quality factors such as juiciness, colour and flavour (Dawson *et al*., 1991; Voller-Reasonover *et al*., 1997; Wattanachant *et al*., 2005a). The principle proteins responsible for meat texture include stromal (mostly collagen) and myofibrillar proteins (Dawson *et al*., 1991; Califano *et al*., 1997). The increment in collagen content and collagen cross-linking in meat (often associated with older animals and specific muscle types) will increase the toughness of cooked meat (Murphy and Marks, 2000). When manufacturing precooked meat products, process temperatures strongly influence texture, protein changes, cooking yield and other important quality factors such as juiciness, color and flavor (Bertola *et al*., 1994; Bouton *et al*., 1981; Doerscher *et al*., 2003; Martens *et al*., 1982; Paul, 1963). The relationships between processing temperature and these quality factors are important in improving the design and operation of thermal processes for foods (Rao and Lund, 1986). Cooking of meat changes the structure of the intramuscular connective tissue and its mechanical properties, because of denaturation of the collagen (Palka, 1999; Christensen *et al*., 2000). Retorting with high temperature denatures the triple helical structure of collagen, which can tenderize the meat. Improvement in the textural and yield characteristics of aseptically processed chicken breast was reported by Dawson *et al.* (1991). Dawson *et al.* (1997) reported the aseptically processing treatment significantly reduced the total collagen content of the hen meat by 27.3% but the broiler meat was not significantly as illustrated in Table 2. The loss of hen meat total collagen in the processed samples, when expressed on a per gram of protein basis, indicates that collagen was extracted by the aseptic processing of hen meat. Furthermore, aseptic processing significantly increased the percentage of soluble collagen in broiler (33.1% increase) and hen (132% increase) meat compared with cooked breast meat. The increase in collagen content and collagen cross-linking in meat (often associated with older animals and specific muscle types) generally increases the toughness of cooked meat (Dawson *et al*., 1991; Rochidi *et al*., 2000). Process time equivalent to F-value at high temperature processing was also found to affect collagen property. According to Voller-Reasonover *et al*. (1997) the lowest processing temperature increased the soluble collagen compared to the highest processing temperature when compared in temperature range 115.6, 121.1 and 126.7°C. This is probably due to the lowest processing temperature had the longest exposure time for equivalent to F-value. The longer time to heat allowed for greater collagen solubilization. However, unacceptable results of texture characteristics including toughening, drying and loss of particulate shape were observed after high temperature processing of chicken breast meat. This is may caused by the heat denaturation of myofibrillar protein and probably connected with gelatinization and loss of intramuscular collagen (Voller-Reasonover *et al.,* 1997; Palka, 1999). In contrast, Palka and Daun (1999) found that the tenderizing of beef *semitendinosus* muscle was occurred when processed at high temperature of 121°C. The different results obtain from different specie muscles may be caused by the difference in muscle type and compositions such as intramuscular collagen (total content and type of collagen) and amount of intramuscular fat.

**Table 2** Total collagen and percentage of heat-soluble collagen in cooked, unprocessed and cooked aseptically processed broiler and spent hen chicken breast

| Sample | Total collagen (mg/g meat) | Total collagen (mg/g protein) | Soluble collagen (% of total collagen) |
|---|---|---|---|
| Cooked broiler[1] | 1.73[c] | 5.56[c] | 28.73[b] |
| Processed broiler[2] | 1.71[c] | 5.23[c] | 38.25[a] |
| Cooked spent hen[1] | 3.44[a] | 10.96[a] | 17.21[c] |
| Processed spent hen[2] | 2.50[b] | 6.89[b] | 39.92[a] |

[1]Cooked to internal temperature at 80ºC

[2]Aseptically processed at 130ºC, short time processing equivalent to F-value

**Source**: Dawson *et al.* (1991)

## OBJECTIVES

1. To study on chemical, physical properties and microstructure of Thai indigenous chicken muscles as influenced by aged and rearing systems.
2. To compare the chemical and physical properties of meat from different breeds (spent hen, broiler and Thai indigenous chicken) and muscle types (*pectoralis major* and *biceps femoris*) before and after heating in Tom Yum soup condition.
3. To determine the effects of thermal processing temperature on the chemical and physical properties of chicken muscles in Tom Yum soup condition.
4. To monitor the changes in chemical, physical properties and microstructure of chicken muscles in Tom Yum soup condition during storage.