GENERAL INTRODUCTION

In developing countries, annual meat consumption sharply increased more than double from 10.2 kg at the beginning of 1960s to 25.5 kg at the late of 1990s (FAO, 2003). Amongst other meat production, the world broiler chicken industry has developed consistently for more than 60 years and occupies the second largest meat production in the world after pork representing 29 percent of meat production from farmed animals (McKay et al., 2003). FAO (2003) reported that during the period of 1964-1999, poultry meat consumption grew more than fivefold and thus makes it the most popular food product worldwide.

In accordance with the increased demand for poultry meat, factors affecting the poultry productivity such as genetics, nutrition, management and disease control should be paid much more attention. In the historical improvement of the broiler production, genetic selection has played an important role in which about 85-90 percent of the improvement in broiler growth rate over the past 45 years was as a result of genetic contribution (Havenstein et al., 2003). An earlier investigation on genetic selection for commercial broiler breeding was done on the basis of feed conversion efficiency (Hess et al., 1941; Fox and Bohren, 1954). Selection based on improving feed conversion efficiency makes chicks deposit less of a retained energy as fat and convert more energy and nitrogen into protein deposition. In the 1990s, the establishment of genetic basis based on feed conversion efficiency declined and changed to physiological factors supporting for feed conversion efficiency e.g. activity of digestive enzymes (O'Sullivan et al., 1992; Dunnington and Siegel, 1995), energy and protein metabolism (Jorgensen et al., 1990; Buyse et al., 1998). The change of growth rate due to breeding success leads to the consequence for nutritionists to re-evaluate the required energy, amino acids and other essential nutrients in animal diets.

Many studies relating to amino acid requirement in chicken have been published (Hewitt and Lewis, 1972; Boomgaardt and Baker, 1973; Hunchar and Thomas, 1976; Kessler and Thomas, 1976; Bilgili et al., 1992; Webel et al., 1996; Alleman et al., 1999; Corzo et al., 2002; D’Mello, 2003; Sterling et al., 2003). However, due to performance changes as the aforementioned, continuous appraisal of amino acid requirements should be performed. There are several factors influencing the amino acid responses of growing chickens for maintenance and tissue deposition including age, sex, genotype, environment and also several dietary factors such as protein and energy levels, and the presence of anti nutritional factors. Hence, amino acid requirements can not be applied to all growing chickens, but depend on the animal factors (age, sex and genotype), dietary factors and environmental factors.

Requirement of amino acids for maintenance and protein deposition

Recently, evaluation of amino acid requirements is done not only to know their nutritional availability for protein deposition but also for their metabolic and maintenance functions. Amino acid requirement for maintenance is normally defined as a nitrogen equilibrium, the state in which nitrogen intake exactly equals the sum of nitrogen losses, therefore the nitrogen content in the body keeps constant (Fuller, 1994). Estimation of maintenance requirement and efficiencies of utilizing indispensable amino acid for the whole body protein accretion has been reported by Edwards et al., (1999a, b) and Sklan and Noy (2005). Hurwitz et al., (1978) reported that amino acid requirements in broiler diets may be allocated as those for maintenance, carcass growth and feather growth. By calculating other target function affecting the amino acid requirements in the animal diets, hence, accurate estimation of amino acids to formulate least cost feed and to reduce animal waste in the environment could be achieved. Kidd et al., (2004) stated that the formulation of the animal diets should closely meet the required amino acids for maintenance and tissue accretion because formulation of amino acids under the requirement level will reduce animal performance and over formulation of amino acid will increase nitrogen excretion.

Protein deposition is a key factor affecting the amino acid requirement in growing animals. Moughan and Fuller (2003) stated that the amino acid required for growing animal is more than 90% for growth process and only less than 10% for maintenance. In modelling of amino acid requirements in growing animals does not only depend on data for maintenance but also on data for protein deposition and the amino acid pattern in protein deposition (Fatufe and Rodehutscord, 2005). Animal has a finite capacity to deposit protein, the excess amino acids in the diets will be deaminated and the carbon skeletons finally degraded. Therefore, the understanding of protein deposition is really essential in formulation of animal feed. It has been understood that maximum protein deposition in growing animal is influenced by genotype, age, and gender (Renden et al., 1994; Smith and Pesti, 1998; Chamruspollert et al., 2002; Rimbach and Liebert, 1999; Sakomura et al., 2005). Sakomura et al., (2005) reported that male animals deposit more protein and less fat compared to female animals. The changes of animals performance as result of genetic selection has been reported by Havenstein et al., (2003). The alteration of genetic leads to changes in performance and the rates of protein and fat deposition in the carcass. Relating to the age, the capacity decreased with the age in growing chickens (Rimbach and Liebert, 1999) and in pigs (Wecke and Liebert, 2005). Due to different capacity for protein deposition as aformentioned factors, the amino acid required by animals will be different according to a targeted amount of protein deposition. The physiological factors affecting amino acid requirements depending on age, sex and genotype will be discussed in the subsequent chapter.

Physiological factors affecting animal growth and amino acid requirement

It has been well documented that age, sex and genotype considerably influence the growth of animals, and consequently lead to differences in required amino acids (Hunchar and Thomas, 1976; Kessler and Thomas, 1976; Leclercq, 1983; Marks and Pesti, 1984; Han and Baker, 1994; Kidd et al., 1997; Corzo et al., 2002; D'Mello, 2003).

Age

The morphological development of the gastrointestinal tract in growing chickens depends on the age. Hence, digestion and absorption of nutrients varies depending on the growth period. In the initial posthatch, endogenous lipid-rich yolk supplies nutrients to the young birds, therefore dietary nutrients may be poorly utilized by poultry during this period. Noteworthy changes in the gastrointestinal tract including secretion of digestive enzymes and the initiation of uptake of amino acids between 4-10 d of age has been reported by Uni et al., (1995). Nitsan et al., (1991) also reported that digestive enzyme concentrations increased through the first 14 d of age. Uni et al., (1999) stated that the ability of the intestinal tissue to digest and absorb nutrients increased sharply during the first week posthatch. Dramatic increase in villus length as a result of elevating the numbers of enterocytes has been reported by Geyra et al., (2001). The high protein deposition during early age has also been concluded by Zuprizal et al., (1992). Due to morphological changes of the gastrointestinal tract and the efficiency of protein deposition with the age period, protein synthesis as the process of anabolism and catabolism may be different between young and old chicken. Studies from Krogdahl and Sell (1988) give support to this conclusion by increased protease activity in the gut of young chickens as compared to older ones.

Studies by Rimbach and Liebert (1999) and Samadi et al., (2004) in chicken and Wecke and Liebert (2005) in pigs indicated that the potential for protein deposition decreased with increasing age. Kang et al., (1985) who examined growth and protein deposition in the breast muscle (pectoralis thoracica) and the leg muscle (gastrocnemius-peroneus) concluded that the fractional rate of protein synthesis reduced markedly from 48 to 16% per day between 1-6 weeks posthaching. During the 5 week period, the fractional rate of protein deposition declined from 33 to 4% per day and from 21 to 4 % per day in the breast and leg muscle, respectively. The experiment conducted by Batal and Parsons (2002) with young broiler chickens (0-21d) showed that the digestibility of amino acids reached a plateau at 10 d of age.

Fonolla et al. (1981) and Zuprizal et al. (1992) reported that protein and amino acid digestibility decreased with increasing age. As a consequence of different growth, the required amino acid of growing chickens may be different depending on the age.

Decreasing of amino acid concentration in the broiler diet with increasing age is clearly reported by NRC (1994). Within the period of 0-3 wk, 3-6 wk and 6-8 wk, the concentration of all essential amino acids in the diet decreased with the age. Labadan et al., (2001) investigated the lysine (Lys) requirement of male chickens for 2 to 3 week interval until 8 weeks. It was found that as requirement calculation based on breast muscle growth 1.32% (digestible 1.24%) at 0-2 of age, 1.21% (digestible 1.11%) at 2-4, 0.99 % (digestible 0.92%) at 3- and 0.83% (0.75% digestible) at 5-8, respectively. Reports from other literature also indicate that the level of amino acids in the diet decreased with the age (Han and Baker, 1994; Kidd et al., 1997; Corzo et al., 2002).

Sex

The effect of sex on the performance of broiler chickens has been reported by Eits et al. (2003). During growing phase (11 to 26 d) male and female broilers had similar response to increased dietary ideal protein levels on FCE and body weight gain (BWG). However, at the finishing phase (26-41 d) the response on FCE and BWG is higher for male broilers. It seems logical that male broilers would require higher levels of amino acid than females, because male chickens contain more protein and less fat in their weight gain (Edwards et al., 1973; Kubena et al., 1974; Han and Baker, 1991). Different strategies of feeding to improve performance of broiler chickens have been carried out by Kidd et al (2005) at different sex and different level of amino acid density (high and moderate). At day 55, male broilers were heavier (BW: 3372g vs. 2898g) with better feed efficiency (FCE: 1.815kg/kg vs. 1.857kg/kg) compared to female broilers. However, at the early age (0-5 d), the chickens fed high density of amino acids were similar in growth between male and female chickens (BW: 0.107 kg vs.

0.106 kg). But, when fed moderate density of amino acid at this period, males tended to be heavier than females (BW: 0.109 kg vs. 0.104 kg).

Han and Baker (1994) conducted an experiment to determine the fecal digestible lysine requirement by adding crystalline lysine to a basal diet assuming the supplemented lysine to be 100% bioavailable for male and female broilers (Ross x Ross) during period 22-43 day. The calculation of data based on broken line analysis indicated that the fecal digestible lysine requirement for maximum BWG was 0.85% for males and 0.78% for females. The requirement of optimal FCE was higher for males 0.89% than for females 0.85%. Studies by Hunchar and Thomas (1976) and Kessler and Thomas (1976) also indicated that the requirement of amino acid is higher in male than in female growing chickens.

Genotype

Protein turnover of growing animals is also affected by genotypes. MacDonald and Swick (1981) compared protein synthesis between meat-type and egg-type chickens. They concluded that the meat-type chickens exhibited higher protein deposition due to lower degradation rates of protein. In the first week, about 68% of the protein synthesis is retained in broilers; meanwhile only about 38% of protein synthesis is retained in egg-type chickens. The review from Simon (1989) shows studies based on fractional synthesis rate of muscle protein and supports the argument that the superior protein deposition in broilers compared with layers is a result of the lower protein degradation rate in broiler genotypes. The different development of the digestive tract amongst genotypes perhaps also influences the growth response of growing animals. As reported by Dror et al., (1977) the weight of ceacum and ileum at 21 d of age is greater in heavy genotypes (White Rock) compared to light genotypes (New Humpshire x White Leghorn). Uni et al. (1995) reported that morphological gastrointestinal tract (duodenum, jejunum and ileum) of heavy strain (Arbor Acres) grows faster compared to light strain (Lohman) at similar age of 14 d.

A study by Smith and Pesti (1998) also shows that genotype affects the performance of broilers in which a high-yield strain cross (Ross x Ross 208) has higher body weight (3.29 vs. 3.10kg), higher feed intake (6.40 vs. 6.11kg) and higher carcass yield (72.51 vs. 71.17%) compared to a fast growing strain cross (Peterson x Arbor Acres). These results are supported by previous researches (Leclercq, 1983; Marks and Pesti, 1984). The different genotypes of broiler chickens raised in a different poultry system (outdoor) also affect the performance of the growing animals. Investigation by Fanatico et al., (2005) using three different genotypes (slow-growing genotype, medium-growing genotype and fast-growing genotype) with the same starter, grower and finisher diets reported that the fast-growing genotype has the greatest breast yield and the lowest feed intake. The slow-growing broiler has the lowest breast yield and the highest feed intake within a production cycle. When slaughtered at the market weight, all genotypes appeared to have similar body weight between 2.1 and 2.5kg at 81 d for slow-growing genotype, at 67 d for medium-growing genotype and at 53 d for fast-growing genotype. The feed efficiency of each genotype is 2.13 for fast-growing genotype, 2.68 for medium-growing genotype and 3.58 for slow-growing genotype.

Other factors also influence the requirement of amino acids in growing broilers such as environment (Morris, 2004) and energy protein ratio (Gous and Morris 1985). Ratio between essential (EAA) and non essential amino acid (NEAA) also affect the optimum growth performance of growing chickens (Stucki and Harper, 1961; Sugahara and Ariyoshi, 1968; Bedford and Summers, 1985). Sugahara and Ariyoshi (1968) observed maximum response on weight gain and N-retention at an EAA:NEAA ratio of 0.54 : 0.46. Adverse effects of amino acid imbalances, antagonisms and toxicities on absorption and utilization may also change amino acid requirement in growing broilers (D'Mello and Lewis, 1970;

Harrison and D'Mello, 1986; Burnham et al., 1992; Emmert and Baker, 1995; Scherer and Baker, 2000). The presence of anti-nutritional factors in common feedstuff may also affect amino acid utilization in growing animals. Liener (1979) stated that the appearance of anti-nutritional factors such as protease inhibitors may increase the requirement of sulphur containing amino acids as a result of increased losses of cystine rich proteolytic enzymes. Phytate-protein complex can also decrease the digestibility of protein, which in turn eventually reduces its utilization (Yi et al., 1996).

Methods for estimating amino acid requirements

The accurate estimation of amino acid for maintenance and efficiencies of utilizing amino acids for protein deposition is a fundamental aspect to formulate animal diets. Thus, the appropriate method to estimate the dietary amino acid requirements in growing animals is very essential. There are several methods used to determine amino acid requirements in growing poultry including empirical methods (graded supplementation technique, diet dilution technique), factorial methods and N-utilization model.

Estimation of amino acid requirement based on empirical methods has been widely used (Hewitt and Lewis, 1972; Boomgaardt and Baker, 1973; Edwards and Baker, 1999a,b; Tesseraud et al., 1999). Based on this approach, the requirement for a certain amino acid is derived from responses of animals to different intake levels of that amino acid, assuming that all amino acids and nutrients supply inadequate, except amino acid under investigation. The response curve may be used to determine estimates of slope and plateau required as important component for calculation of amino acid requirements (Fisher, 1994). A number of criteria are used to measure the responses of amino acid requirement in growing chickens including growth rate, feed conversion efficiency, protein deposition. Amino acid requirement of growing chickens is expressed in concentration in the diet. According to this method, there are two techniques used, namely graded supplementation technique and diet-dilution technique.

In determination of amino acid requirements based on graded supplementation technique, it is really imperative to supply basal diet with all sufficient amino acids except amino acids under study. Graded doses of the crystalline amino acids are employed to generate amino acids response from extreme low to extreme high (Gous and Morris, 1985; Morris et al., 1999). However, graded supplementation technique has been criticized due to the imbalance of amino acids at each successive dose of the limiting amino acids and the response may be influenced by this factor. Therefore, Fisher and Morris (1970) introduced diet-dilution technique based on the sequential dilution of a high-protein "submit" diet with isoenergetic protein free mixtures. The precipitation of deleterious effects in amino acid imbalance could be overcome by applying diet-dilution technique (D'Mello and Lewis, 1970). According to Gous and Morris (1985), the "submit" diet should contain all amino acids in excess amount (e.g 1.80 times of assumed requirement), except amino acids under investigation, which is at lower concentration (e.g 1.40 times of assumed requirement). When mixture amino acid used in the diet is low, concentration of amino acids under study must be low (e.g. 0.6 times of assumed requirement). But, the relative ratios of amino acids in all diets have to be similar and the amino acid under study is always the first limiting amino acid (Gous and Morris, 1985). This technique has been applied in many studies (Pilbrow and Morris, 1974; Gous and Morris, 1985; Morris and Abebe, 1990; Thong and Liebert, 2004a).

Due to the criticism of graded supplementation technique and the doubt of diet-dilution technique, Hurwitz et al. (1978) introduced factorial methods for the prediction of growth responses to amino acids. Based on this approach, dietary amino acid requirement depends not only on amino acid requirement for production but also on the estimate of maintenance requirement for individual amino acids. To estimate the maintenance requirement of chickens, data from empirical methods are still used (Gous and Morris, 1985).