MUSCLE FIBER DIAMETER AND FAT TISSUE SCORE IN QUAIL (Coturnix-coturnix japonica L.) MEAT AS AFFECTED BY DIETARY TURMERIC (Curcuma longa) POWDER AND SWANGI FISH (Priacanthus tayenus) MEAL

W. Kartikayudha¹, Isroli², N. H. Suprapti¹ and T. R. Saraswati¹

¹Faculty of Science and Mathematics, Diponegoro University, Tembalang Campus, Semarang 50275 – Indonesia
²Faculty of Animal and Agricultural Sciences, Diponegoro University, Tembalang Campus, Semarang 50275 – Indonesia

Corresponding E-mail : yudha.kaka@yahoo.co.id

Received August 25, 2013; Accepted October 29, 2013

ABSTRAK

Tujuan penelitian ini adalah untuk mengevaluasi pengaruh penggunaan tepung kunyit dan ikan swangi terhadap ukuran diameter serat otot dan jaringan lemak major pectorales dan semimembranosus pada daging puyuh. Penelitian menggunakan rancangan acak lengkap pola faktorial 2x3, yaitu faktor pertama adalah jenis ransum terdiri RA : ransum standar dan RB : 85% ransum standar + 15% tepung ikan swangi, dan faktor kedua adalah periode pemberian tepung kunyit terdiri dari 3 level yaitu P0 : tanpa diberi tepung kunyit; P1 : diberi tepung kunyit 54 mg/ekor/hari sejak berumur 210 hari; P2 : diberi tepung kunyit 54 mg/ekor/hari sejak berumur 14 hari. Perbedaan bermakna antar kelompok perlakuan dianalisis menggunakan uji Duncan’s Multile Range Test pada taraf signifikasi 95%. Hasil penelitian menunjukkan bahwa combinasi perlakuan tepung kunyit dengan RA (P0 : 2,33 µm; P1 : 3,06 µm; P2 : 2,98 µm) maupun dengan RB (P0 : 2,22 µm; P1 : 3,12 µm; P2 : 2,92 µm) meningkatkan secara nyata (P<0.05) diameter serat otot pada major pectorales. Kombinasi tepung kunyit dengan RA dan dengan RB juga meningkatkan secara nyata (P<0.05) diameter serat otot pada semimembranosus. Kesimpulan penelitian ini adalah suplementasi tepung kunyit pada ransum RA dan RB meningkatkan secara nyata (P<0.05) ukuran dari diameter serat otot pada major pectorales dan semimembranosus.

Kata Kunci : serat otot, jaringan lemak, tepung ikan swangi, tepung kunyit

ABSTRACT

The objectives of this study were evaluate the dietary turmeric powder and swangi fish meal on size of muscle fiber diameter and fat tissue score of major pectorales and semimembranosus of quail meat. Research was conducted based on 2x3 of factorial completely randomized design, in which the first factor was 2 types of diet, i.e. RA : standard diet; RB : 85% standard diet + 15% swangi fish meal, and the second factor was 3 levels of period time of turmeric powder addition, i.e. P0 : without turmeric powder; P1 : turmeric powder 54 mg/quail/day was given since quail age 210 days old; P2 : turmeric powder 54 mg/quail/day was given since quail age 14 days old. Difference of means between treatment groups were analyzed by Duncan’s Multiple Range Test in 95% significance level. The results showed that combined treatment of turmeric powder with RA (P0 : 2.33 µm; P1 : 3.06 µm; P2 : 2.98 µm) and RB (P0 : 2.22 µm; P1 : 3.12 µm; P2 : 2.92 µm) increased (P<0.05) muscle fiber diameter on major pectorales significantly. Muscle fiber diameter on semimembranosus were increased (P<0.05) by combined treatment of turmeric powder with RA (P0 : 2.83 µm; P1 : 3.50 µm; P2 : 3.24 µm) and RB (P0 = 2.85 µm; P1 = 3.28 µm; P2 = 3.33 µm). In conclusion, combined treatment of RA (standard diet) and RB (diet with Swangi fish meal) increased (P<0.05) the size of muscle fiber diameter in major pectorales and semimembranosus.

Keywords : muscle fiber, fat tissue, swangi fish meal, turmeric powder
INTRODUCTION

Quail meat may contribute the fulfillment of meat production at present time although quail meat production is not as big as other poultry meat (Genchev et al., 2008). Beside having high productivity of eggs, quails can produce high nutrition meat. Quail meat can be used as an alternative choice because it contains high level protein. Birds are generally culled when their productivity have declined (Ionță et al., 2010).

Quail meat quality is not only determined by the protein content in the meat, but also it could be determined by meat tenderness. Consumers generally like tender meat (Dransfield et al., 1984; Genchev et al., 2008). Muscle fiber diameter and fat tissue are important factors affect the tenderness of meat (Crouse et al., 1991; Nishimura et al., 1999). The big diameter of the muscle fibers and low score of fat tissue produce tough meat, while the small diameter of muscle fibers and a high score of fat tissue produce tender meat (Chartrin et al., 2006; Seideman et al., 1987).

Some factors, such as activity and nutrition levels, may affect the size of muscle fibers diameter and fat tissue of meats (Cribb and Hayes, 2006; Migdal et al., 2004; Petersen et al., 1998). Muscles having a high activity level usually have a big muscle fibers diameter. It is due to the high activity that can increase muscle contractions which cause muscle hypertrophy and causes the enlargement of the muscle fibers diameter. High activity in muscle also causes low score of fat tissue, because fat has been depleted to support the exercise activity. Fat tissue is basically energy reserves that may be used at any time when muscle need more energy caused by high activity (Horowitz, 2003; Romijn et al., 1993; Seideman et al., 1987).

Dietary may affect the tenderness of meat. The muscle fiber diameter and fat tissue of meats may be influenced by nutrient levels, beside the exercise activity factors (Bruns et al., 2005; Migdal et al., 2004). High protein content in the diet may be a precursor to develop muscle fibers, whereas high carbohydrate and fat content in the diet could be a source of energy for muscle activity (Praseno, 2001; Baty et al., 2007).

Providing feed additive in diet may improve the quality of poultry meat, because diet could affect muscle fiber and fat tissue of meats (Stahl et al., 2005). Chemical compound in turmeric powder and swangi fish meal may play a role in quail metabolism, so that it may influenced the tenderness of quail meat.

Swangi fish meal contains essential amino acids (Kittipattanabawon et al., 2005). Lysine and methionine that contained in swangi fish meal have an important role in endogenous synthesis of carnitine in the body. Carnitine is an essential factor in long-chain fatty acid oxidation. It acts as a carrier of fatty acyl groups from the cytoplasm to the mitochondrion. Deficiency of carnitine may reduced the ability of body to transport long-chain fatty acids into mitochondria (Feller and Rudman, 1988; Hoppel, 1982).

Turmeric powder contains 3-4% curcumin that can increase protein metabolism in the body (Chattopadhyay et al., 2004; Rahmat and Kusnadi, 2008; Raju et al., 2012). Curcumin in turmeric powder also play a role in fat metabolism. Akram et al. (2010) stated that turmeric could stimulate bile production, and increase the bodies ability to digest fats. The study on the role of turmeric powder and swangi fish meal as feed additives is important to provide information about its dose and the proper period time of turmeric powder to optimize metabolism and improve quail meat product.

This study was conducted to clarify the effect of turmeric powder and Swangi fish meal supplementation on metabolism and meat tenderness in female quail.

MATERIALS AND METHODS

Experimental Diet and Quail Management

Materials used in this study were 90 females quail (Coturnix-coturnix japonica L), turmeric (Curcuma longa), turmeric powder, swangi fish (Priascanthus tayenus) meal, standard diet, alcohol (70%, 80%, 90%, 96%, absolute), toluol, glycerin, paraffin, canndan balsam, 0.9% NaCl, aquadest, husk, drinking water, desinfectants (composition Cetylpyridium 1%, Cetyltrimethyl Ammonium Chloride Bromide and Benzalkonium Chloride 2%), anti-stress vitamin (vitamin A, D3, E, K, B1, B2, B6, B12, C, nicotic acid, calcium-D-pantohenate, electrolytes such as sodium, potassium, calcium, and magnesium), and liquid sugar.

Quail Acclimatization and Grouping

There were two kinds of cages used during
the study, those were collective and battery cages. Acclimatization process for quail adaptation is done in collective cages for 2 weeks, and was continued at battery cage for 1 week. After completing the period of accimatization, 90 quails were distributed into 30 boxes battery cage system. One box battery cage contained 3 quails. Quails were divided into 6 groups, so each treatment group consisted of 15 quails.

**Diet Types**

Two types of diets were used in this study, i.e. standard diet (RA) and high protein diet (RB). Standard diet used in this study was the commercial consisted of corn, bran, soybean, coconut, peanut, meat flour, bone flour, leaves powder, wheat, canola, vitamins, calcium, phosphorus, and minerals. High-protein diet (RB) consisted of 85% standard diet and 15% swangi fish meal. The nutrient composition of standard diet (RA) and high protein diet (RB) are presented in Table 1.

**Muscle and Fat Tissue Measurements**

Variables assessed in this study were muscle fibers diameter and fat tissue score of quail meats. Meat samples were taken from the major pectorales and semimembranosus of quail meats. In this study, the muscle tissue samples were taken about 1 cm x 1 cm. Fixation process for quail meat samples (major pectorales and semimembranosus) was done using bouin solution (a compound fixative used in histology), and then muscle histology preparat was made with paraffin method. After making histological preparation, staining process was done using Hematoxylin-eosin (HE) (Suntoro, 1983).

Observations were conducted on the histological structure of muscle tissue component (muscle fiber and fat tissue) in 5 different visual fields by using 10x10 magnification light microscopy. Muscle fiber diameter was measured by using 40x10 magnification light microscopy (Suwiti, 2008).

The other histological structures of meat and fat tissue were analyzed using quantitative analysis or by scoring. When fat tissue was not formed, the 0 point was given. When a few fatty tissues (only found a number of fat tissues in 1 visual field from histological sample was found, the 1 point was given. When it was found much fat tissues (a number of fat tissues were found in 2 different visual field or more from histological sample), the 2 point was given (Suwiti, 2008).

**Data Analysis**

Research was conducted based on 2x3 of factorial completely randomized design, in which the first factor was 2 types of diet (RA: standard diet; RB: 85% standard diet + 15% Swangi fish meal), and the second factor was 3 levels of period time of turmeric powder addition (P0:

---

**Table 1. Nutrient Composition of Standard Diet (RA) and High Protein Diet (RB)**

| Nutrient                  | RA  | RB  |
|---------------------------|-----|-----|
| Water content (%)         | 11.66 | 12.18 |
| Crude protein (%)         | 22.76 | 25.19 |
| Crude fat (%)             | 4.38  | 4.92 |
| Crude fiber (%)           | 5.70  | 4.15 |
| Calcium (%)               | 3.68  | 4.40 |
| Phosphorous (%)           | 0.73  | 0.82 |
| Ash (%)                   | 6.79  | 7.05 |
| Carbohydrate (%)          | 54.41 | 41.29 |
| Cholesterol (g/100g)      | 0.82  | 0.68 |
| Energy metabolism (Kcal/kg)| 2890 | 2920 |
| Amino acids:              |     |     |
|  · Lysine (ppm)           | 16000 | 16598 |
|  · Methionine (ppm)       | 672   | 1048 |
without turmeric powder; P1 : turmeric powder 54 mg/quail/day was given since quail age was 210 days old; P2 : turmeric powder 54 mg/quail/day was given when quail age was 14 days old.

The collected data were analyzed by analysis of variance. Duncan’s Multiple Range Test was performed for mean comparison with 95% significance levels.

**RESULTS AND DISCUSSION**

**Muscle Fiber Diameter**

Standard diet (RA) and diet with swangi fish meal (RB) without turmeric powder did not show significant effect on the size of muscle fiber diameter of major pectorales (RAP0 : 2.33 µm; RBP0 : 2.22 µm) and semimembranosus (RAP0 : 2.83 µm; RBP0 : 2.85 µm) (Table 2). Crude protein content of two diet (RA : 22.76%, RB : 25.19%) did not affect size of diameter muscular fiber of major pectorales and semimembranosus of quail meats. In the layer phase, quails require 20% of feed protein. Feeds that are not completely digested by the bodies are passed through the gastrointestinal tract and excreted into the litter. The result was lost of nutrient (Hassan et al., 2011; NRC, 1994).

Table 2 shows that supplementation of turmeric powder in combination with RA (standard diet) and RB (diet with Swangi fish meal) resulted in significantly increased (P<0.05) on the size of muscle fiber diameter in major pectorales and semimembranosus. This phenomenon is caused by absorption and protein metabolism in the gastrointestinal tract and liver of bodies which could be enhanced by supplementing turmeric powder. Curcumin (a compound from turmeric powder) protects hepatocytes cell activity (hepatoprotective) and increases the secretion of pancreatic enzymes.
tripsin, chymotrypsin) that increases protein metabolism. It also increase mucin secretion, acting as gastro-protectant against irritants, and has some good effects on the intestine (Chattopadhyay et al., 2004; Platel and Srinivasan, 2000; Rathaur et al., 2012).

Increasing protein metabolism in the body is not only increase protein deposition, but also increase deposition of myofibril. The more number of myofibril resulted in the larger the size of muscle fiber diameter. Myofibril protein is a major part in the meat tissue that has functioned in muscle contraction. It consists of myosin (60-70% of total protein myofibrils), actin (20-25% of total protein myofibrils), and regulatory proteins (tropomyosin, troponin). Increasing a number of myofibrils enlarge (hypertrophy) muscle fiber diameter. Several factors, such as activity, growth, and nutrition, can influence the size of muscle fiber diameter (Cribb and Hayes, 2006; Gunawan,
The size of muscle fiber diameter between *semimembranosus* and *major pectorales* muscle fibers are shown in Table 2. Diameter size of *semimembranosus* muscle fibers was larger than those of *major pectorales* muscle fibers because *semimembranosus* muscle is more active than *major pectorales* muscle. Baar and Esser (1999) stated that high resistance exercise training was correlated well with hypertrophy. Training rats twice a week for 6 weeks resulted in 13.9% and 14.4% hypertrophy in the extensor digitorum longus and tibialis anterior muscles, respectively. Rennie and Tipton (2000) stated that muscle hypertrophy resulted from exercise activity is caused by an increase in muscle protein synthesis in the resting and recovering of muscle. Suwiti (2008) stated that muscle fiber diameter will undergo physiological atrophy and reduction in the size of muscle fiber diameter if it is never used.

Large size from the muscle fiber diameter of *semimembranosus* in this study demonstrated that curcumin (a compound from turmeric powder) and exercise activity are even more potent to build muscle and protecting against muscle atrophy, and it made *semimembranosus* tougher than *major pectorales*. Chen *et al.* (2007) reported a positive relationship between muscle fiber diameter and meat tenderness. Chen (2011) also found highly correlated between muscle fiber diameter and shear force (tenderness) (*r* : 0.833). Seideman *et al.* (1987) stated that the increasing number of myofibrils per unit area which caused larger muscle fibers tougher than small muscle fibers.

**Fat Tissue**

Fat tissue (intramuscular fat) of quail meat is presented in Table 2, and they were found in a few amounts. Nishimura *et al.* (1999) stated that intramuscular fat was deposited mainly between bundles of muscle fibers, within the perimysium (Figure 2).

Table 2 shows that the different period times of turmeric powder addition in the diet of quail did not significantly affect the fat tissue of *major pectorales* muscle (*P*0 : 1.38; *P*1 : 1.13; *P*2 : 0.88) and *semimembranosus* (*P*0 : 1.13; *P*1 : 0.63; *P*2 : 0.50) in quail meat. Turmeric powder 54 mg/quail/day that was added in the diet of quail was not effectively reduce fat content (Akram *et al.*, 2010; Souza *et al.*, 2003; Widodo, 2002).

Table 2 showed that there was not significant effect between standard diet and diet which were added swangi fish meal in the fat tissue of *major pectorales* (*RA* : 1.25; *RB* : 1.00) and *semimembranosus* (*RA* : 0.83; *RB* : 0.67) of quail.
meats. Energy metabolism and fat contained in the two levels of quail diet (Table 1) were not much different, the fat tissue of quail meat (major pectorales and semimembranosus) were not significantly different. Trayhurn and Beattie (2001) stated that the fat tissue stores increase in periods of positive energy balance and declines when energy expenditure is higher than that of intake. The average score of fat tissue in semimembranosus was lower than those of major pectorales (Table 2), because semimembranosus muscle was more active than major pectorales. More activities from semimembranosus muscle make it having a few number of fat tissues. Solichedi et al. (2003) stated that lipid content in femoral muscle is lower than those in pectoral muscle because femoral muscle is more active than pectoral muscle. Horowitz (2003) stated that exercise activity could improve the coordination on fatty acid mobilization, uptake and oxidation, and therefore reduce the potential for lipid accumulation in muscle.

Low score from the fat tissue of semimembranosus muscle in this study demonstrated that exercise activity is even more potent to decrease the deposited fat in muscle, and it caused semimembranosus tougher than major pectorales. DeVol et al. (1988) reported a positive relationship between fat content and meat tenderness \( r = 0.32 \). Chartrin et al. (2006) also reported a positive relationship between fat content and meat tenderness \( r = 0.43 \). Nishimura et al., 1999) stated that a large amount of deposited fat in muscle can contribute to tenderization of meat by disorganizing the structure of intramuscular connective tissue. It bring about a weakening of the intramuscular connective tissue, and contributing to tenderization of meat.

CONCLUSIONS

Turmeric powder supplementation which combined with RA (standard diet) and RB (diet with Swangi fish meal) increased the size of muscle fiber diameter in major pectorales and semimembranosus.

ACKNOWLEDGEMENTS

The authors thank to Directorate General of Higher Education for Unggulan Scholarship. The authors also thank to Tyas Rini Saraswati from Department of Biology, Faculty of Science and Mathematics, Diponegoro University, for allowing to use animals from her nutrition experiments in this research.

REFERENCES

Akram, M., S. Uddin, A. Ahmed, K. Usmanghani, A. Hannan, E. Mohiuddim and M. Asif. 2010. Curcuma longa and curcumin. Rom. J. Biol. Plant Biol. 55(2):65-70
Baar, K., and K. Esser. 1999. Phosphorylation of p70(S6k) correlates with increased skeletal muscle mass following resistance exercise. Am. J. Physiol. 276(1):120-127
Baty, J.J., H. Hwang, Z. Ding, J.R. Bernard, B. Wang, B. Kwon and J.L. Ivy. 2007. The effect of a carbohydrate and protein supplement on resistance exercise performance, hormonal response, and muscle damage. J. Strength and Conditioning Research. 21(2):321-329
Bruns, K. W., R. H. Pritchard and D. L. Boggs. 2005. The effect of stage of growth and implant exposure on performance and carcass composition in steers. J. Anim. Sci. 83 (1):108-116
Chartrin, P., Meteau, H. Juin, M.D. Bernadet, G. Guy, C. Larzul, H. H. Réemignion, J. Mourot, M.J. Duclos and E. Baeza. 2006. Effects of intramuscular fat levels on sensory characteristics of duck breast meat. Poult. Sci. 85(5):914-22
Chattopadhyay, I., K. Biswas, U. Bandyopadhyay and R.K. Banerjee. 2004. Turmeric and curcumin: biological actions and medical applications. Current Science. 87(1):44-53
Chen, Q.L. 2011. Correlation between beef tenderness and fiber diameter or connective tissue content. J. Food Sci. 33(13):126-129
Chen, X. D., Q. G. Ma, M.Y. Tang and C. Ji. 2007. Development of breast muscle and meat quality in Arbor Acres broilers, Jingxing 100 crossbred chickens and Beijing fatty chickens. Meat Sci. 77(2):220–227
Cribb, P. J. and A. Hayes. 2006. Effects of supplement timing and resistance exercise on skeletal muscle hypertrophy. Med. Sci. in Sports & Exercise. 11:1918-1925
Crouse, J.D., M. Koohmaraie and S.D. Seideman. 1991. The Relationship of muscle fibre size to tenderness of beef. Meat Sci. 30: 295-302.
DeVol, D. L., F. K. McKeith, P. J. Dechel, J. Novakofski, R. D. Shanks and T. R. Carr.
1988. Variations in composition and palatability traits and relationships between muscle characteristics and palatability in a random sample of pork carcasses. J. Anim. Sci. 66(2):385-395

Dransfield, E., G. R. Nute, T. A. Roberts, R. Boccard, C. Touraille, L. Buchter, M. Casteels, E. Cosenteno, D. E. Hood, R. L. Joseph, J. Schon and E. J. C. Paardekooper. 1984. Beef quality assessed at European research centres. J.Meat. Sci. 10(1):1-20

Feller, A.G. and D. Rudman. 1988. Role of carnitine in human nutrition. J. Nutr. 118(5):541-547

Genchev, A., G. Mihaylova, S. Ribarski, A. Pavlov and M. Kabakchiev. 2008. Meat quality and composition in Japanese quails. Trakia J. Sci. 6(4):72-82.

Gunawan, A. 2001. Mekanisme dan Mekanika Pergerakan Otot. INTEGRAL. 6 (2) : 58-71.

Hassan, H.M.A., M.O. Abd-Elsamee, A.E. El-Sherbiny, A. Samy and M.A. Mohamed. 2011. Effect of protein level and avizyme supplementation on performance, carcass characteristics and nitrogen excretion of broiler chicks. Am-Euras. J. Agric. Environ. Sci. 10 (4):551-560

Hoppel, C. L. 1982. Carnitine and carnitine palmitoyltransferase in fatty acid oxidation and ketosis. Fed. Proc. 41(12):2853-2857

Horowitz, J.F. 2003. Fatty acid mobilization from adipose tissue during exercise. Trend in Endocrin. Metabolism. 14(8):386-392

Ioniţă, L., P. Micloşanu, E.C. Roibu, and I. Custură. 2010. Bibliographical study regarding the quails’ meat quality in comparison to the chicken and duck meat. Lucrări Ştiinţifice - Seria Zootehnie. 56:224-229

Kittiphatthanabawon, P., S. Benjakul, W. Visessanguan., T. Nagai and M. Tanaka. 2005. Characterisation of acid-soluble collagen from skin and bone of bigeye snapper (Priacanthus tayenus). J. Food Chemistry. 89:363-372

Loenneke, J.P. 2012. Skeletal Muscle hypertrophy: How important is exercise intensity? J. Trainology. 2:28-31

Migdal, W., P. Pasciak, D. Wojtysiak, T.Barowicz, M. Pieszka and M. Pietras. 2004. Effect of CLA addition in feed for fatteners for meat quality, eating quality and dietary value of m. longissimus dorsi. J. Meat. Sci. 66(4): 863-870.

Nishimura, T., A. Hattori and K. Takahashi. 1999. Structural changes in intramuscular connective tissue during the fattening of Japanese Black Cattle, effect of marbling on beef tenderization. J. Anim. Sci. 77(1):93-104.

NRC [National Research Council]. 1994. Nutrient Requirements of Poultry. 9th Ed. National Academy of Sciences. Washington D.C.

Petersen, J.S., P. Henckel, N. Oksbjerg, and M. T. Sorensen. 1998. Adaptations in muscle fibre characteristics induced by physical activity in pigs. J.Anim. Sci. 66(3):733-740.

Platel, K. and K. Srinivasan. 2000. Influence of dietary spices and their active principles on pancreatic digestive enzymes in albino rats. Nahrung. 44:42-46

Praseno, K. 2001. Fisiologi Hewan. Diponegoro University Press. Semarang.

Rahmat, A. and E. Kusnadi. 2008. Pengaruh penambahan tepung kunyit (Curcuma domestica Val.) dalam ransum yang diberi minyak jelantah terhadap performan ayam broiler. Jurnal Ilmu Ternak. 8(1):25-30

Raju, A.H.H., D. M. Mamatha, M. R. Rao and V.K.Kanji. 2012. Impact of turmeric on the protein and lipid metabolic profiles of silkworm, Bombyx mori L. and cocoon production. Current Biotica. 6(2):208-226

Rathaur, P., W. Raja, P.W. Ramteke and S.A. John. 2012. Turmeric : The golden spice of life. IJPSR. 3(7):1987-1994.

Rennie, M.J., and K. D. Tipton. 2000. Protein and amino acid metabolism during and after exercise and the effect of nutrition. Annu. Rev. Nutr. 20 : 457–483.

Romijn, J.A., E.F. Coyle, L.S. Sidossis, A. Gastaldelli, J.F. Horowitz, E. Endert and R.R. Wolfe. 1993. Regulation of endogenous fat and carbohydrate metabolism in relation to exercise intensity and duration . A.M. J. Physiol. 265 : E380-E391.

Schoenfeld, B.J. 2010. The mechanisms of muscle hypertrophy and their application to resistance training. J. Strength and Conditioning Res. 24(10):2857-2872

Seideman, S.C., M. Koohmaraie and J.D. Crouse. 1987. The influence of muscle fiber size on tenderness in a-maturity heifers. J.Food Quality. 11(1):27-34

Solicedi, K., U. Atmomarsono, dan V.D. Yunitanto. 2003. Pemanfaatan Kunyit (Curcuma Domestika VAL) Dalam Ransum Broiler Sebagai Upaya Menurunkan Lemak

Effect of Feed Additive on Quail Meat (W. kartikayudha et al.) 271
Abdominal dan Kadar Kolesterol Darah. J. Indon. Trop. Anim. Agric. 28 (3): 172-178.

Souza, D.N.D., D.W. Pethick, F.R. Dunshea, J.R. Pluske and B.P. Mullan. 2003. Nutritional manipulation increases intramuscular fat levels in the Longissimus muscle of female finisher pigs. Aust. J.of Agric.Res. 54:745-749.

Stahl, C.A., M.S. Carlson-Shannon, B.R. Wiegand, D.L. Meyer, T.B. Schmidt and E.P. Berg. 2005. The influence of creatine and a high glycemic carbohydrate on the growth performance and meat quality of market hogs fed ractopamine hydrochloride. Meat Science. 75:143-149

Suntoro, S.H. 1983. Metode Pewarnaan (Histologi dan Histokimia). Bhratara Karya Aksara. Jakarta.

Suwiti, N. 2008. Identifikasi daging sapi Bali dengan metode histologis. Majalah Ilmiah Peternakan. 11(1):31-35

Trayhurn, P. and J.H. Beattie. 2001. Physiological role of adipose tissue : white adipose tissue as an endocrine and secretory organ. Proc. the Nutr. Society. 60:329-339.

Widodo, W. 2002. Nutrisi dan Pakan Unggas Kontekstual. Departemen Pendidikan Nasional. Jakarta.